PR

S
1
J8

UNIVERSITY
OF MICHIGAN
FEB 21 1955
FORESTRY
LIBRARY

Journal of ECONOMIC ENTOMOLOGY

Published by the
ENTOMOLOGICAL SOCIETY OF AMERICA
Formed in 1953 by Consolidation of the
American Association of Economic Entomologists
(1889–1952)
and the former
Entomological Society of America (1906–1952)

VOLUME 48 February · 1955 NUMBER 1

JOURNAL OF ECONOMIC ENTOMOLOGY

Published by
ENTOMOLOGICAL SOCIETY OF AMERICA

F. W. Poos, *Editor*, 1530 P St., N.W.,
Washington 5, D.C.

EDITORIAL BOARD

R. L. METCALF, *Chairman*, Riverside, Calif. (Section B, 1955)

D. E. HOWELL, Stillwater, Okla. (Section D, 1956)

G. E. BOHART, Logan, Utah. (Section C, 1957)

F. S. ARANT, Auburn, Ala. (Section F, 1958)

E. L. CHAMBERS, Madison, Wis. (Section E, 1959)

A bimonthly journal published on the 15th of February, April, June, August, October, and December, devoted to the interests of economic entomology. The authors are entirely responsible for statements in the *Journal*, whether of fact or opinion.

TERMS OF SUBSCRIPTION. Non-members in the U.S.A., Cuba, Mexico and Canada—$10.00. Non-members in other countries—$10.00 plus 60¢ postage. Single copies $1.75 plus postage of 10¢ per copy. Deliveries overseas are not guaranteed and foreign mailings are made at the subscriber's risk. LOST NUMBERS. Missing numbers cannot be supplied free of charge unless notice is received within 60 days after the appearance of issues concerned.

REPRINTS. No gratis copies are supplied. A schedule of prices which will apply to orders received before the *Journal* is printed, and an order form are sent with proof. For price schedule, see Vol. **48**:117. February, 1955.

BUSINESS COMMUNICATIONS of the Society and SUBSCRIPTIONS AND MATTERS PERTAINING TO ADVERTISEMENTS should be sent to the Executive Secretary, Entomological Society of America, 1530 P Street, N.W., Washington 5, D.C. Change of address must reach the office of the Executive Secretary 45 days prior to the month of issue to be effective for that month. Members should make use of postal regulations providing for forwarding of second class mail by guaranteeing postage upon delivery.

MANUSCRIPTS and other copy for the *Journal* as well as all correspondence concerning *Journal* content, should be addressed to the editor. Prompt publication of acceptable matter may be secured by payment of the cost of printing and engraving ($16.00 per page plus cost of engravings with additional charge for excessive tabular matter.) Cost of engravings in excess of $15.00, for each eight printed pages or major fraction thereof, will be charged to the author. Before preparing manuscripts for publication in the *Journal*, authors are urged to consult the Publication Policies and Manuscript Rules and Suggestions given in Vol. **48**(1): 115-7, February, 1955.

Entered as second class matter at the Post Office at Menasha, Wisconsin. Acceptance for mailing at special rate of postage under the provisions of Sec. 34.40, Par. (D), provided for in the Act of February 28, 1925, embodied in paragraph 4, Section 538, P. L. and R., authorized May 1, 1936.

PRINTED BY THE GEORGE BANTA PUBLISHING CO.,
MENASHA, WISCONSIN

ISSUED FEBRUARY 16, 1955

JOURNAL OF ECONOMIC ENTOMOLOGY
ENTOMOLOGICAL SOCIETY OF AMERICA
Formerly Official Organ American Association of Economic Entomologists

Vol. 48 February, 1955 No. 1

An Ecological Study of the Leafhopper Vectors of Blueberry-Stunt[1]

MARTIN T. HUTCHINSON

A virus disease of cultivated blueberries, commonly known as "stunt," has been the subject of intensive research since it was described by Wilcox in 1942. In 1950, Tomlinson *et al.* reported that the physically-similar leafhoppers, *Scaphytopius* (*Cloanthanus*) *magdalensis* (Prov.) and *Scaphytopius* (*Cloanthanus*) *verecundus* (Van D.) were co-vectors of the disease. The present study, and that of Dr. Karl Maramorosch as also reported in this issue, indicate that *Scaphytopius magdalensis* is a vector of stunt disease, and that *S. verecundus* is not a vector.

Although *Scaphytopius magdalensis* had been identified from New Jersey blueberry fields in 1945 by Dr. P. W. Oman of the Entomology Research Branch, U.S. Department of Agriculture, *S. verecundus* was unknown in New Jersey prior to October, 1949, when Dr. Oman identified it from insects used in the successful transmission tests. Previously, *S. verecundus* was considered to be limited to areas south of North Carolina (Hepner 1947) or possibly as far north as northern Virginia (Stearns 1927). *S. magdalensis*, on the other hand, had long been reported as occurring along the Atlantic seaboard from Canada to Florida. In addition, Dr. Oman did not identify any of the leafhoppers trapped in New Jersey blueberry fields from 1946 to 1948 as being *S. verecundus*. However, the insects used in transmission tests with stunt disease were obtained principally from cultivated cranberry bogs and from the surrounding pineland[2] that is native throughout the New Jersey cranberry and blueberry-growing region. It is in these areas that *S. verecundus* has been found in large numbers.

TAXONOMIC CONSIDERATIONS.—The external similarity of these two insects caused considerable confusion in the early identification of leafhoppers from cranberry bogs. Beckwith & Hutton (1929) state that *Platymetopius*[3] *magdalensis* "feeds on cranberries principally, if not exclusively." They cite Dr. Herbert Osborn as the authority for the identification. *S. verecundus* is not mentioned. Dobroscky (1931) lists *S. magdalensis* as the second most numerous of 44 species of leafhoppers found on cranberry bogs. Again, *Scaphytopius verecundus* is not mentioned. As recently as 1944, Dr. John S. Caldwell of the U. S. Department of Agriculture identified *S. magdalensis* from a cranberry bog at Rockwood, N.J. However, in the fall of 1951, seven male leafhoppers and three nymphs collected from this same bog were identified by the writer as being *S. verecundus*, on the basis of genital characters and nymphal color patterns. Since the present study shows that *S. magdalensis* is very rarely found on cranberry bogs, the insect referred to by these previous workers is undoubtedly *S. verecundus*.

Accurate determination of the adult male insects requires examination of the genitalia, and there is reason to believe that such examinations were not made when leafhoppers were collected from cranberry bogs prior to 1947. Hepner (1947) says of *S. magdalensis* "As might be expected from its wide range, this species varies considerably. Specimens from Florida are much smaller, but the small process near middle of paraphysis readily separates this species from any other, with the exception of *nigrifrons*, which is much darker." And for *S. verecundus*, "Resembling *magdalensis*, but smaller with a longer crown and without lateral process on paraphysis . . . the sharp crown and reddish color readily separate this species from any other." Specimens of *S. verecundus* collected in New Jersey, however, are not notably reddish, but are of about the same color as *S. magdalensis*; the male being dark brown to brownish black and the female being lighter brown (Fig. 1). External structural differences in this material are so uncertain that Dr. Oman stated in a letter to the writer (March 30, 1950) "I am still not able to separate *verecundus* and *magdalensis* with certainty, except in the typical form, without recourse to the structures of the male genitalia." In this regard, Dr. David A. Young, Jr.[4] commented in a letter (November 13, 1952) as follows: "Except for illustrations of a very few species appearing in earlier works, genital characters were not employed for identification in the group now referred to as *Scaphytopius* until the revisional study made by Hepner in 1947. I would not rely on determinations made before this date, unless the species in question possessed gross distinctive characters—a qualification not met by the species you've been working with, in my opinion."

No mention has been made by any writer consulted concerning the separability of the females of *Scaphyto-*

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, the State University of New Jersey, Department of Entomology, New Brunswick. Accepted for publication August 20, 1954.

[2] This environment, that is commonly referred to as the New Jersey "pines," is marked by intermixed stands of pine (*Pinus rigida* and *P. echinata*) and oak (*Quercus ilicifolia* and *Q. prinoides*). The Ericaceous ground cover beneath these trees is predominately huckleberry (*Gaylussacia baccata* and *G. frondosa*, blueberry (*Vaccinium vacillans* and *V. pallidum*), and sheep laurel (*Kalmia angustifolia*). However, nearly two dozen additional Ericaceous and closely-related plant species are commonly found in this environment. This total plant association, with all its variations in the relative abundance of native plant species, is designated in this paper as "pineland." Geographically, the "pines" area is contained principally within the southeastern quarter of the state, with a few small outlying areas in central and southwestern New Jersey.

[3] An older generic name of this insect.

[4] U. S. Department of Agriculture, Agricultural Research Service, Entomology Research Branch.

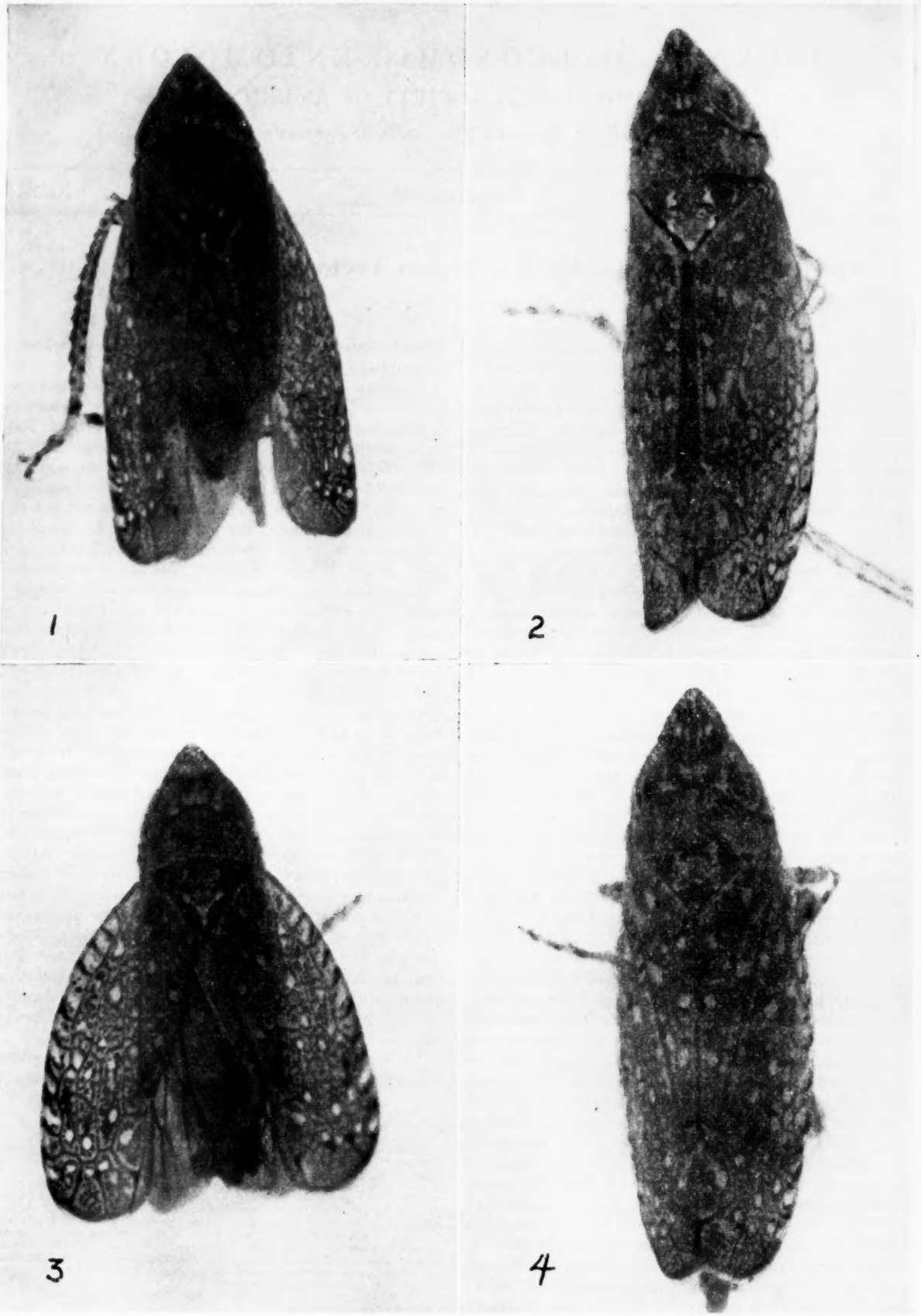


FIG. 1.—The "sharp-nosed" leafhoppers, *Scaphytopius* (*Cloanthanus*) *magdalensis* and *S. verecundus:* 1. *S. magdalensis*, male 2. *S. magdalensis*, female 3. *S. verecundus*, male 4. *S. verecundus*, female.

pius magdalensis and *S. verecundus*. The gential plates of each, as figured by Hepner (1947), show only very minor differences, and observations by the present writer indicate that these are not reliable. Therefore no attempt was made in this study to distinguish females of either species, except as they were reared from identified nymphs.

The nymphs of the two species were not studied by previous workers. They are quite distinct and can in almost all cases be readily identified by differences in color and color-pattern.

Problems arising from mistaken identification of similar insects are not new in studies of virus vectors. Turner (1946) states that *Macropsis insignis* (Fitch), a species very difficult to distinguish from the reported peach yellows vector, *Macropsis trimaculata* (Van D.)[5], may have been used with the latter in transmission tests, since both species have the same geographic range and food habit. Likewise, Baker (1949, 1950) notes that in the adult stage, *Scaphoideus luteolus* (Van D.), the vector of elm phloem necrosis, closely resembles other species in the genus. However, nymphs of these *Scaphoideus* species above second instar are readily distinguishable.

FIG. 2.—Sticky-board trap after exposure in a blueberry field. Arrows indicate specimens of *S. magdalensis*. The larger leafhoppers are *Graphocephala coccinea*, Forster, (Photo courtesy W. E. Tomlinson, Jr., Mass. Agr. Expt. Sta.)

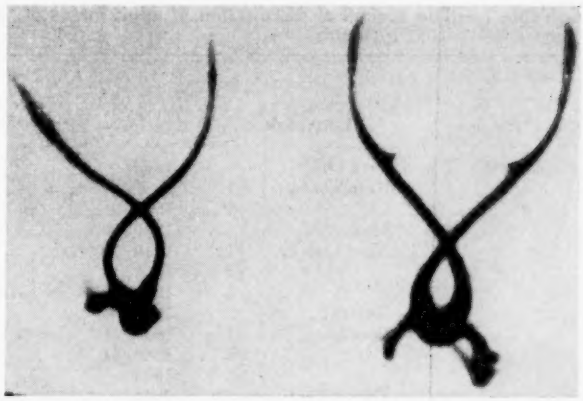


FIG. 3.—Paraphyses of *S. verecundus* (left) and *S. magdalensis* (right). Note lateral processes on paraphyses of *S. magdalensis*.

MATERIALS AND METHODS.—The survey upon which this paper is based was made during the 6-year period 1949 through 1954, in the course of which over 12,000 adult male leafhoppers were identified. The adult leafhoppers were collected on sticky-board traps identical with those used by Tomlinson *et al.* (1950); being 5″×9″ boards painted chrome yellow and smeared with a proprietary sticker[6] (Fig. 2). Traps were suspended from wooden standards with a short piece of wire, at varying distances above the ground. Standards were placed in cultivated blueberry fields, cultivated cranberry bogs, and pine woodlands. Traps were generally replaced at biweekly intervals. The insects were removed from the boards with a dissecting needle and were washed consecutively in xylene, acetone and 70 per cent alcohol, to remove the sticker and prepare them for examination. Adults were also collected by sweeping with a heavy muslin beating net. The nymphs were collected only by sweeping, since they are rarely obtained by trapping. Swept insects were transferred from the net to a changing cage,[7] where they were removed with an aspirator and placed into 70 per cent alcohol. Since blueberry bushes are difficult to sweep, sweeping was done principally in cultivated cranberry bogs and pine woodlands. The survey was made extensively throughout the principal cranberry and blueberry-growing regions of southern New Jersey, and preliminary surveys were made in Maine, Pennsylvania, and several other states.

Identification of adult male insects was based upon the presence or absence of lateral processes on the paraphyses (Fig. 3). The insects were examined in 70 per cent alcohol under a binocular microscope at 30×, and the genital capsule was pressed open to reveal the paraphyses. The paraphyses were dissected out of the abdomen when casual examination did not reveal the presence of lateral processes, in order to be certain as to whether or not they were present. The nymphs were readily distinguished in all instars by their color-pattern. No attempt was made to distinguish female insects. Identification of all material

[5] Breakey (1932) describes differences in male genitalia and nymphal color pattern that clearly separate these two species. The aedeagus of *Macropsis trimaculata* is flaringly bifurcate at the apex, whereas that of *M. insignis* is stylate. Beirne (1954) confirms and illustrates the difference between the male genitalia. Both writers agree that the females are difficult to distinguish.

[6] "Pestix" (Sherwin-Williams).

[7] A fibre-board box, 2½ feet square, open at one end and screened with fine mesh plastic screen at the other.

Table 1.—The ecological distribution of adult males of *Scaphytopius magdalensis* and *S. verecundus* collected in New Jersey, 1949–1952 inclusive.

Environment	Location		Season	Total Males	*S. magdalensis*		*S. verecundus*	
					No.	Per Cent	No.	Per Cent
Blueberry fields	Fort Dix		1949–50	46	46	100.0	0	0.0
	Hammonton	#1	1949	29	29	100.0	0	0.0
		#2	1952	178	178	100.0	0	0.0
	Magnolia		1949–50	320	319	99.7	1	0.3
	New Lisbon	#1	1949–50	67	66	98.6	1	1.4
		#2	1952	168	168	100.0	0	0.0
		#3	1949–50	1390	1379	99.1	11	0.9
	Retreat		1949	47	47	100.0	0	0.0
	Speedwell	#1	1950–51	170	167	98.3	3	1.7
		#2	1949–51	746	745	99.9	1	0.1
		#3	1952	73	73	100.0	0	0.0
	Upton Station[a]		1950	225	188	83.5	37	16.5
	Weymouth		1952	17	17	100.0	0	0.0
	Whitesbog		1951	28	28	100.0	0	0.0
Cranberry bogs	Hampton Gate		1950[b]	16	0	0.0	16	100.0
	New Lisbon		1950[b]	29	0	0.0	29	100.0
	Retreat		1951	14	0	0.0	14	100.0
	Rockwood		1950[b]	7	0	0.0	7	100.0
	Speedwell[c]		1951	310	14	4.5	296	95.5
	Upton Station	#1	1950	703	8	1.1	695	98.9
		#2	1950[b]	100	0	0.0	100	100.0
		#3	1950	102	4	3.9	98	96.1
		#4[d]	1950	308	93	30.2	215	69.8
		#5[e]	1950	131	6	4.6	125	95.4
	Whitesbog		1950–52[b]	73	0	0.0	73	100.0
Pineland	New Lisbon	#1	1950	1727	744	43.1	983	56.9
		[f]	1950	174	163	93.7	11	6.3
			1949–51[b]	126	69	54.8	57	45.2
			1952[b]	143	100	69.9	43	30.1
		#2	1950	1416	182	12.7	1234	87.3
			1949–50[b]	67	7	10.4	60	89.6
	Speedwell		1950	666	225	33.8	441	66.2
		[f]	1951	1265	1258	99.4	7	0.6
			1950–51[b]	15	10	66.7	5	33.3
	Upton Station		1950	577	211	36.5	336	63.5
		[f]	1950	215	188	87.4	27	12.6

[a] Small field of young plants, surrounded by cranberry bogs and wild Ericaceae.
[b] Collected by sweeping by insect net; all other collections by trap.
[c] Small bog, surrounded by wild Ericaceae including highbush blueberries.
[d] Traps 20 feet from heavy growth of wild highbush blueberries.
[e] Trap 15 feet from heavy growth of wild Ericaceae.
[f] Traps in shaded and heavily shaded areas, in contrast to open areas.

Note; Pineland vegetation (exclusive of pine and oak); New Lisbon #1, mainly *Kalmia angustifolia, Dendrium buxifolium* and *Leucothoe racemosa* in that order; New Lisbon #2, almost exclusively *Chamaedaphne calyculata* with some *Kalmia angustifolia;* Speedwell, mainly *Kalmia angustifolia, Gaylussacia baccata* and *Vaccinium vacillans* in that order; Upton Station, at least 8 different Ericaceous plants, including most of those listed above.

collected during 1949 was made by Dr. Oman. Subsequent identifications were made by H. W. Moulter[8] and the author—on the basis of comparison with the 1949 material.

Table 2.—Summary of the ecological distribution of adult males of *Scaphytopius magdalensis* and *S. verecundus*, collected in New Jersey, 1949–1952 incl.

Environment	Method of Collection	Total Locations	Total Insects	*S. magdalensis*		*S. verecundus*	
				No.	Per Cent	No.	Per Cent
Blueberry fields	Trapping	14	3504	3450	98.3	54	1.7
Cranberry bogs	Trapping	6	1578	125	8.0	1453	92.0
	Sweeping	5	225	0	0.0	225	100.0
Total		11	1803	125	6.9	1678	93.1
Pineland							
Open	Trapping	4	4389	1362	31.0	3027	69.0
Open	Sweeping	3	336	176	52.4	160	47.6
Shaded	Trapping	3	1654	1609	97.2	45	2.8
Total		10	6379	3147	49.3	3232	50.7

Individual nymphs were reared to adults in microcages. These cages were also used to contain individual adult insects which were used in transmission tests. The cages were made with a small felt ring (inside diameter, $\frac{11}{16}$"; height, $\frac{3}{16}$") topped by a perforated celluloid cover. The felt rested on the upper surface of a blueberry leaf and a square of corrugated cardboard was placed underneath the leaf. The cover, the felt, the leaf and the cardboard were held together with a binder clip. Insects were introduced into the cage from an aspirator placed under an edge of the celluloid cover. The petiole of a blueberry leaf easily carried the unsupported weight of a microcage.

All other work with the two leafhoppers was done inside large lantern-globe cages. These were ventilated at the top by cheesecloth stretched over an embroidery hoop, and at the bottom by a wide metal collar, covered

[8] Assistant in cranberry and blueberry culture, N. J. Agr. Expt. Sta.

Table 3.—Individual laboratory rearing of the two forms of *Scaphytopius* nymphs found in surveys in New Jersey.[a]

	Nymphs, Used, Number	Adults Reared				
		Male			Total	
		magdalensis	*verecundus*	Female	Number	Per Cent
Form A	126	44	0	58	102	81
Form B	124	0	21	20	41	33

[a] Nymphs in 3rd, 4th, and 5th instar, respectively, were reared in micro-cages on leaves of the blueberry, *Vaccinium ashei*, at New Brunswick, N. J. during the winter of 1950–1951.

half with celluloid and half with wire screen. Separate colonies of the two species were maintained by transferring nymphs from collections obtained by sweeping pineland vegetation.

ECOLOGICAL SURVEY.—Of the more than 400 male leafhoppers of the *Scaphytopius magdalensis-S. verecundus* group that were collected by trapping in blueberry fields in 1949, all proved to be *S. magdalensis*. However, the male insects from collections made by sweeping pineland areas proved to include both *S. magdalensis* and *S. verecundus*. These and subsequent surveys (Table 1 and 2) showed clearly that the two species were separated ecologically, *S. magdalensis* being abundant in blueberry fields, and virtually absent from cranberry bogs, whereas *S. verecundus* was abundant in cranberry bogs, but virtually absent from blueberry fields. Both species are abundant in pineland areas, with *S. verecundus* being mainly restricted to open, sunny environments. Occasionally, *S. magdalensis* can be found in small numbers on cranberry bogs, as can *S. verecundus* in blueberry fields (Table 1). However, this has been noted only when traps are placed near the margins of fields or bogs, adjacent to heavy growth of wild Ericaceous plants, or when the field or bog is not more than a few hundred feet wide. In these cases, the insects are probably migrating into and across such areas, rather than maintaining themselves there. Male leafhoppers of both species appeared to be more readily trapped than were female leafhoppers,[9] which places a limitation on the accuracy of population studies made by trapping. Where practical, sweeping appears to give more reliable results.

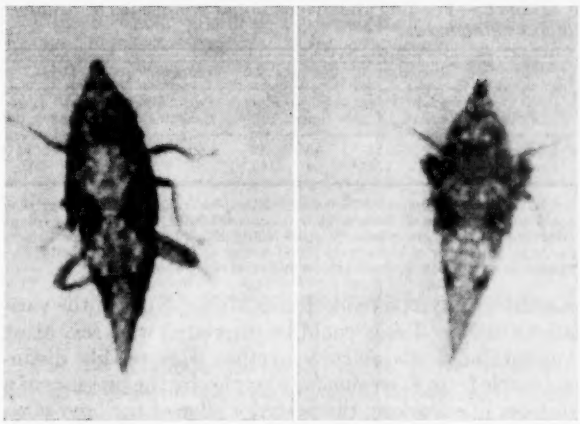


FIG. 4.—Nymphs of *S. magdalensis* (left; 5th instar) and *S. verecundus* (right; 4th instar).

Nymph surveys were begun as soon as it was suspected that the nymphs of the two species could be distinguished. In the spring of 1950, nymphs with two different color patterns were collected together in sweeping pineland (Fig. 4). A short time later, only one of these forms was found while sweeping cranberry bogs. Individual rearing of these two forms of nymphs (Table 3) showed that Form A, typically a brown or brownish-black nymph with a white hour-glass marking on the dorsum, was *Scaphytopius magdalensis*. Similarly, Form B, a nymph with the dorsal thorax red, the sides of the thorax and abdomen black, and with an extended yellow, hour-glass marking on the dorsal abdomen was *S. verecundus*. Six distinct color-variants of the *S. magdalensis* nymphs were noted in New Jersey. One of the most unusual had a thick, black stripe across the lower abdomen, together with red-orange wing pads. Another variant was of a uniform sandstone-red color, with the hour-glass marking being outlined in small white dots. Several variants, similar to those noted in New Jersey, were also noted among *S.*

[9] During 1950, females collected from blueberry fields by trapping averaged 17 per cent of 3947 leafhoppers. Females trapped from pineland averaged 16 per cent of 5252 leafhoppers, while females swept from pineland averaged 40 per cent of 361 leafhoppers. Over a period of 10 days, females trapped from a cranberry bog averaged 8 per cent of 366 leafhoppers, whereas females swept from the same bog averaged 51 per cent of 202 leafhoppers.

Table 4.—Ecological distribution of nymphs of *Scaphytopius magdalensis* and *S. verecundus* collected by sweeping in New Jersey, 1950–53 inclusive.

Environment	Location	Season	Total Nymphs	*S. magdalensis*		*S. verecundus*	
				No.	Per Cent	No.	Per Cent
Blueberry fields	Speedwell	1950	8	8	100.0	0	0.0
Cranberry bogs	Hampton Gate	1950	2	0	0.0	2	100.0
	Lakewood	1953	15	0	0.0	15	100.0
	New Lisbon	1950	2	0	0.0	2	100.0
	Rockwood	1950	3	0	0.0	3	100.0
	Upton Station	1950–52	168	1	0.4	167	99.6
	Whitesbog #1	1950, 1952	30	3	10.0	27	90.0
	Whitesbog #2	1953	45	2	4.4	43	95.6
Pineland							
Open	New Lisbon	1950–53	191	116	60.8	75	39.2
Shaded	Speedwell	1951	11	11	100.0	0	0.0

Table 5.—Feeding and ovipositional preference of *Scaphytopius verecundus*.[a]

Plant	Replicate 1		Replicate 2		Replicate 3		Total	
	Positions	Eggs laid	Positions	Eggs laid	Positions	Eggs laid	Positions	Eggs laid
Blueberry	79	43	49	48	60	41	188	132
Cranberry	18	174	43	190	31	216	92	580

[a] Each replicate comprised 20 female leafhoppers (taken from a colony that contained males) in a lantern globe cage containing one blueberry plant (Harding var.) and one cranberry plant (Early Black var.). "Positions" refers to the total number of leafhoppers found resting or feeding on the plants. The figures given for each replicate represent a total of six observations.

magdalensis nymphs collected in Maine. None of the variations in New Jersey could be correlated with sex. Most variants of *S. magdalensis* nymphs were readily distinguishable from *S. verecundus* nymphs, by the presence of a distinct line marking the posterior edge of the hour-glass pattern in *S. magdalensis*, and by the fact that *S. magdalensis* nymphs are never red and yellow. The *S. verecundus* nymphs differed among themselves mainly in the intensity of the colors, with cream sometimes replacing yellow, and brown or tan replacing black. Although the nymphs of the two species are readily distinguishable in nearly all cases, detailed study shows many of their markings to be similar.

The somewhat more limited nymph survey confirmed the results of the adult survey, as shown in table 4. This ecological survey, indicating the virtual absence of *Scaphytopius verecundus* from cultivated blueberry fields, is circumstantial evidence that *S. magdalensis* is the vector of stunt disease in these areas.

POSSIBLE REASONS FOR THE ECOLOGICAL SEPARATION. *Food preference.*—At first, the most logical reason for the separation of the two species appeared to be food preference, or the lack of ability of *Scaphytopius verecundus* and *S. magdalensis* to maintain themselves on blueberry and cranberry, respectively. However, a large number of tests, including the continuous rearing of both species on either cranberry or blueberry, showed that this could not be the reason. Studies of the feeding and oviposition preferences of *S. verecundus* (Table 5)—adapted from the method of Wilcox (1951)—showed that although blueberry might be preferred for feeding, cranberry was definitely preferred for oviposition. This may indicate that females of *S. verecundus* prefer cranberry for oviposition under natural conditions. However, such a preference would not appear to exclude *S. verecundus* from blueberry fields to the extent indicated in table 1.

Plant height.—Since the cultivated blueberry is a high-growing plant (from 5 to 8 feet) and the cranberry a low-growing one (from 6 to 10 inches), the question of a preference based on plant height was investigated by the use of traps placed at varying distances above the ground in open pineland where both insects occur. Wooden standards, with cross-arms placed so that the lower edges of the traps were suspended at heights of 5 feet, 2½ feet, and at ground level, were located in five adjacent areas. As shown in table 6, males of both species were found in the same approximate proportion on traps at all three levels; indicating that a preference based upon plant height is unlikely.

Shade.—Since a blueberry field offers considerable shade, whereas a cranberry bog offers very little, the complex of factors concerned with shade and lack of shade was briefly investigated. As shown in tables 1 and 2, *Scaphytopius verecundus* is practically absent from shaded pineland areas, whereas it is abundant in open pineland areas that have similar vegetation. This difference in the population of *S. verecundus* between adjacent pineland areas is almost as striking as the virtual absence of *S. verecundus* from blueberry fields. In open, sunny areas, nearly 70 per cent of the male insects collected were *S. verecundus*, whereas in deeply shaded areas, less than 1 per cent were *S. verecundus*. In contrast, *S. magdalensis* definitely prefers shaded areas of blueberry fields to more open areas. As shown in table 7, over 30 times as many *S. magdalensis* adults were trapped in heavily shaded areas as were trapped in open areas of a single blueberry field. The above evidence indicates that *S. verecundus* may be absent from blueberry fields because it will not tolerate much shade. Likewise, *S. magdalensis* may be kept from cranberry bogs because it will not tolerate extensive open areas. Whether temperature, light intensity, humidity, or a combination of these factors are concerned has not been investigated.

SPECIFIC DIFFERENCES.—Whether *Scaphytopius magdalensis* and *S. verecundus* are actually different species takes on added interest because of a remark by Dr. Oman, in a letter dated March 30, 1950: "Were it not for this bit of evidence (the first finding of ecological separation), I would be almost willing to believe that the morphological differences upon which the separation of these forms is based is of no significance. . . ." In this regard, even the determining physcial character—the lateral process on the male paraphysis—shows considerable variation. Some of the processes are long and slender, while others are short and stout. However, the males of one form always appear to have them, and the males of the other to lack them. As has been noted, the nymphs of the two forms show reliable differences in color and in color-pattern. Other comparisons follow:

Food plants.—Even though both species will feed and reproduce readily on the highbush blueberry (*Vaccinium*

Table 6.—Vertical distribution of *Scaphytopius magdalensis* and *S. verecundus* in open pineland at New Lisbon, N. J., 1950.[a]

Height of Traps	Male		Females (Both Species)
	magdalensis	*verecundus*	
5 ft.	17	6	18
2½ ft.	208	206	98
ground level	521	771	182

[a] Each figure represents the total number of insects recovered from five traps during the period 6/2/50 to 10/24/50.

Table 7.—Population of *Scaphytopius magdalensis* in relation to different environments within a blueberry field.[a]

Environment	Deeply Shaded	Moderately Shaded	Slightly Shaded	Open
Number of Traps	4	18	6	11
Total leafhoppers	265	755	113	21
Leafhoppers, av./trap	66.2	42.0	18.9	1.9

[a] Hammonton, N. J. 5/12/49 to 10/14/49. Figures given include both male and female insects. Since only *magdalensis* males were identified from these collections, it is assumed that the females were also *magdalensis*.

corymbosum L.) and on the cranberry (*Oxycoccus macrocarpus* (Ait.)), distinct differences in the food plants of the two insects have been found. As shown in table 8, *S. magdalensis* cannot maintain itself on *Kalmia angustifolia* L., the "sheep laurel" common in the New Jersey pinelands, whereas *S. verecundus* can maintain itself on this plant. Four trials were made, each with 10 *S. magdalensis* nymphs, and although some matured, no eggs or young nymphs were found. In two similar trials with *S. verecundus*, the nymphs matured, eggs were laid, and a total of 43 second generation nymphs was obtained. Also, although *S. magdalensis* was able to survive on *Chamaedaphne calyculata* (L.)[10] in laboratory tests, it is of interest that of 1411 males of both species trapped from a nearly pure stand of this plant at New Lisbon, N. J. during 1950, 1231 were *S. verecundus*.

Both leafhoppers thrived in the greenhouse on *Leucothöe racemosa* (L.), the "fetterbush," which was apparently even more suitable for *S. magdalensis* than were either cranberry or blueberry. *Lyonia mariana* (L.), the "staggerbush" was tested only with *S. magdalensis*, and appeared to be a suitable host plant. Colonies of both species were maintained on *Vaccinium ashei* Reade, the southern "rabbiteye" blueberry, and on *Vaccinium vacillans* Torrey, the dwarf dryland blueberry common to New Jersey.

Geographic distribution—The two insects appear to differ in their geographic distribution. *Scaphytopius magdalensis*, described by Provancher in 1889 from Quebec, Canada, has been found south to Florida and westward, with decreasing frequency, to the Rocky Mountains (Hepner 1947). Surveys conducted independently by P. E. Marucci[11] and the writer indicate that this species is rare in the blueberry-growing regions of Michigan, and apparently absent from the blueberry fields at Long Beach, Washington. *Scaphytopius verecundus*, described by Van Duzee from Florida in 1910, has been found north to New Jersey, as previously noted.

Surveys made by the writer and Dr. Eugene H Varney[12] in 1953 and 1954 in northern New Jersey, New England, Pennsylvania, West Virginia and Maryland, by sweeping Ericaceous plants growing in open woods or along roadsides, show the presence of *Scaphytopius magdalensis* and the absence of *S. verecundus*. Moderate numbers of *Scaphytopius magdalensis* were collected in New Jersey at Cedar Pond (Passaic County); in Maine at South Sanford, North Leeds, Highmoor, and Rumford; in New Hampshire at Pinkham Notch; in Pennsylvania at Woodward, Bear Meadows (Centre County), and Rainsburg; in West Virginia at Durbin; and in Maryland at Hampstead. No specimens of *S. verecundus* were found. All the above collections were made during the second and third weeks of July.

A collection made by W. E. Tomlinson, Jr.[13], on sticky-board traps in pineland at Waltham, Mass, in late September, 1951, also included moderate numbers of *Scaphytopius magdalensis*, but no *S. verecundus*.

The only exception to the above records is the collection of a single male specimen of *Scaphytopius verecundus* by Dr. F. H. Lathrop[14] near Blue Hill, Maine, in 1950, by sweeping *Gaylussacia spp.* Seven males of *S. magdalensis* were collected at the same time. Identifications were made by the writer.

Table 8.—Food plants of *Scaphytopius magdalensis* and *S. verecundus* as determined in the greenhouse.

Insect	*Vaccinum corymbosum*	*Oxycoccus macrocarpus*	*Kalmia angustifolia*	*Chamaedaphne calyculata*	*Leucothoe racemosa*
S. magdalensis	3–4	3–4	1	2	4
S. verecundus	3–4	4	2–3	3	3–4

Key: 1—A few 3rd to 5th instar nymphs will mature and the adults live for periods up to several months, *but without laying viable eggs.*
2—Slow development of most 3rd to 5th instar nymphs to adult. *Some viable eggs laid.*
3—Moderately rapid development. Moderate numbers of viable eggs laid. *Sufficient for a continuous colony to be maintained.*
4—Rapid development. *Large numbers of viable eggs laid.* Marked longevity of adults.

The environments surveyed in the above areas are similar to those in which *Scaphytopius verecundus* is found in the New Jersey pines region, i.e. open stands of *Vaccinium vacillans* Torrey and *Gaylussacia baccata* (Wang.), with occasional plants of *Kalmia spp.* Likewise, the times chosen for the surveys corresponded phenologically with the periods of abundance of *S. verecundus* at New Lisbon, N. J. In addition, *S. verecundus* was not collected in extensive sweeping of a bog containing *Chamaedaphne calyculata* near Cedar Pond in northern New Jersey on July 9, 1954, or from a *Chamaedaphne* bog near Highmoor, Maine on July 17, 1953. Neither were any *S. verecundus* collected on five sticky-board traps exposed from July 1 to July 10, 1954 in a *Chamaedaphne* bog near Helmetta in central New Jersey. Likewise, traps placed in two Massachusetts cranberry bogs by W. E. Tomlinson, Jr. during the fall of 1951 failed to collect *S. verecundus*. Therefore, present information based upon collections from its known food plants, indicates that *Scaphytopius verecundus* is essentially a southerly insect, which is found in numbers only as far north as the main area of the New Jersey pines region.

Life cycle.—The life cycles of the two insects are quite similar. Both have two generations per year; the first generation in pineland areas begining in early June, and the second in late August. However, as shown by surveys during June of 1951, 1952, and 1953, *Scaphytopius magdalensis* males have appeared in pineland areas from 1 to 2 weeks earlier than have *S. verecundus* males. This may also be a factor in isolating the two species, although the time required between ecdysis and mating is not known for either species. Two years' rearing of both species over the winter in a cool greenhouse has shown that eggs of *S. magdalensis* hatch from 1 to 4 weeks earlier than the eggs of *S. verecundus*. As would be expected, males of both species appear earlier than the females, and the females are more numerous in late autumn. The eggs of both species are inserted into the leaf, between the upper and lower surfaces. Both species have five nymphal instars, with the nymphal period for each species lasting about 1 month.

Parasites.—A similar Dryinid parasite (identification by Dr. Oman) was found to parasitize adults of both species. Of 10,000 insects examined, 17 *Scaphytopius magdalensis* males, 4 *S. verecundus* males, and five fe-

[10] The "leatherleaf" that occasionally covers large, boggy areas in the New Jersey pinelands.
[11] Assoc. Research Specialist in Entomology, N. J. Agr. Expt. Sta.
[12] Plant Pathologist, Horticultural Crops Research Branch, U. S. Department of Agriculture.
[13] Assoc. Research Prof., Cranberry Station, East Wareham, Mass.
[14] Entomologist, University of Maine, Orono, Me.

Table 9.—Results of attempts to cross-mate adults of *Scaphytopius magdalensis* and *S. verecundus* on Early Black cranberry.

Number of	Male *mag.* × Female *mag.*	Male *ver.* × Female *ver.*	Male *mag.* × Female *ver.*	Male *ver.* × Female *mag.*	Check—No Insects Introduced
Insects Used	3♂×4♀	3♂×4♀	4♂×4♀	4♂×4♀	0
Eggs Found (Unhatched)	28	22	3[a]	14[a]	0
Nymphs Found	40[b]	22[b]	0	0	0
Adults Found after 90 days	1	2	0	3[c]	0

[a] Eggs shrivelled.
[b] Including 5th instar nymphs.
[c] Probably those originally introduced.

males—presumably comprising both species—were found to be obviously parastized. Nymphs of *S. magdalensis* were found to be parasitized in two cases.

Cross-mating.—As shown in table 9, successful mating did not occur between the two species in preliminary tests. Under similar conditions, mating occurred readily between males and females of the same species. The apparently sterile eggs laid by females mated to males of the opposite species do not necessarily indicate mating, since isolated females of *S. magdalensis* have been noted to lay sterile eggs.

Ability to transmit blueberry-stunt.—There is no evidence to indicate that *Scaphytopius verecundus* can transmit the blueberry-stunt virus, whereas the writer obtained transmission as the result of the feeding of a single male of *S. magdalensis* in August, 1951. Most of the transmission tests were made with *S, verecundus*, because of the strong circumstantial evidence that *S. magdalensis* was the stunt vector in cultivated blueberry fields.

A total of 40 tests was made with *S. verecundus* during 1950, 1951, and 1953. These involved some 500 nymphs and adults, and over 100 rooted cuttings and seedling plants of *Vaccinium corymbosum*. None of these plants appeared to be diseased during the year following their exposure. The leafhoppers were pre-fed for 2 weeks or more on diseased plants, and were then fed for periods up to 3 weeks on the healthy plants. Tests by Dr. Karl Maramorosch of the Rockefeller Institute for Medical Research, as also reported in this issue, confirm these findings.

DISCUSSION.—The physical similarity of these two clearly different leafhoppers presents an interesting addition to our knowledge of speciation. A comparison might be made with the now-famous finches found by Charles Darwin on the Galapagos Islands, where 13 distinct species—many of which are physically similar—were produced from a presumed common ancestor. In that case, the prerequisites for speciation were considered to have been geographical and ecological isolation, non-competition for food supply, and eventual inability to interbreed (Lack 1953). An apparently identical development has occurred with the two leafhoppers considered in this paper.

SUMMARY.—The leafhoppers, *Scaphytopius* (*Cloanthanus*) *magdalensis* (Prov.) and *Scaphytopius* (*Cloanthanus*) *verecundus* (Van D.) are physically similar insects. The adult males of the two species can be distinguished by examination of the genitalia, and the nymphs are readily distinguished in all instars by differences in color and color-pattern. The females are practically indistinguishable.

The two species are almost completely separated ecologically, with *Scaphytopius magdalensis* present in blueberry fields and *S. verecundus* in cranberry bogs. Both species occur in the surrounding pinelands, with *S. verecundus* being virtually absent from heavily shaded areas. Both species were found in semi-open pineland in comparable numbers at various distances above the ground. The reason for the ecological separation seems to be that *S. verecundus* will not tolerate shaded areas, and *S. magdalensis* will not tolerate extensive open areas.

Both leafhoppers can maintain themselves readily on either blueberry or cranberry. However, they differ in their ability to maintain themselves on two other plant species.

The geographical distribution of the two insects appears to be different, with *Scaphytopius magdalensis* being much better adapted to northerly conditions.

The life cycles of the two insects are similar, except that the eggs of *Scaphytopius verecundus* hatch later in the spring in New Jersey. Both species are parastized by a similar Dryinid parasite. The two species could not be cross-mated in a limited number of tests.

Scaphytopius magdalensis has been shown to be capable of transmitting blueberry-stunt virus, whereas *S. verecundus* has not.

REFERENCES

Baker, W. L. 1949. Studies on the transmission of the virus causing phloem necrosis of American elm, with notes on the biology of its insect vector. Jour. Econ. Ent. **42**(5): 729.

Baker, W. L. 1950. Recent developments on transmission of elm phloem necrosis disease. Proc. Ent. Soc. Wash. **52**(1): 52.

Beckwith, C. S., and S. B. Hutton 1929. Life history notes on some leafhoppers that occur on New Jersey cranberry bogs. Jour. N. Y. Ent. Soc. **37**(4): 425–7.

Beirne, B. P. 1954. The *Prunus* and *Rubus*-feeding species of *Macropsis* (Homoptera: Cicadellidae). Can. Ent. **86**(2): 86–90.

Breakey, E. P. 1952. A review of the Nearctic species of *Macropsis* (Homoptera: Cicadellidae). Ann. Ent. Soc. Amer. **25**: 787–884.

Dobroscky, I. D. 1931. Studies on cranberry false blossom disease and its insect vector. Contrib. Boyce Thompson Inst. **3**(1): 59–83.

Hepner, L. W. 1947. A revision of the tribe Scaphytopini (Homoptera, Cicadellidae) in North America. Univ. Kans. Sci. Bull. **31** (Part 2, No. 16): 413–541.

Lack, D. 1953. Darwin's finches. Sci. Amer. **188**(4): 66–72.

Stearns, L. B. 1927. The Cicadellidae (Homoptera) of Virginia. Va. Agr. Expt. Sta. Tech. Bull. **31.**

Tomlinson, W. E., Jr., P. E. Marucci, and C. A. Doehlert. 1950. Leafhopper transmission of blueberry stunt disease. Jour. Econ. Ent. **43**(5): 658–62.

Turner, W. 1946. Distribution of plum-feeding species of *Macropsis*. Jour. Econ. Ent. **39**(3): 394–5.

Wilcox, R. B. 1942. Blueberry stunt, a virus disease. U.S.D.A. Bur. Pl. Ind. Pl. Dis. Reptr. **26**(9): 211–3.

Wilcox, R. B. 1951. Tests of cranberry varieties and seedlings for resistance to the leafhopper vector of false-blossom disease. Phytopath. **41**(8): 722–35.

The Comparative Effect of a Sulfone in Pyrethrum and Allethrin Mixtures as House Fly Sprays[1]

W. A. Gersdorff, Norman Mitlin, and R. H. Nelson, *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*

In 1947 Synerholm *et al.* reported that a number of sulfoxides and sulfones containing the methylenedioxyphenyl group in the molecule were promising synergists in pyrethrum mixtures against the house fly, *Musca domestica* L. One of the most promising of the former class of compounds, known as sulfoxide, is now being produced commercially and is used in sprays and aerosols containing pyrethrum or allethrin. A quantitative comparison of the effects of this compound with the two insecticides was made in this laboratory against the house fly by the turntable method (Gersdorff *et al.* 1952).

A representative of the sulfones was obtained from a commercial source. Its chemical name, 1,2-methylenedioxy-4-[2-(octylsulfonyl)propyl] benzene, shows that it differs structurally from the sulfoxide, which is the corresponding sulfinyl compound, only in possessing the SO_2 instead of the SO group. A description of its preparation and physical properties is given by Starr & DiSanto (1953). A comparison of the effects of this compound in pyrethrum and allethrin mixtures has been made by the same methods as were used for the sulfoxide study and is reported in this paper.

Materials and Methods.—The sample of the sulfone was of technical grade. That of allethrin was 94 per cent pure as determined by the hydrogenolysis method. In the sample of pyrethrum extract 53 per cent of the total pyrethrins consisted of pyrethrin I and cinerin I, as determined by the mercury-reduction method.

Stock solutions of the two insecticides were prepared by dissolving them in refined kerosene. Because the sulfone was not completely soluble in that solvent, 20 per cent acetone was used as an auxiliary solvent in preparing a stock solution as well as sprays of this adjunct alone. Sprays of the insecticides alone and their mixtures with sulfone were prepared from the stock solutions, dilution being made with refined kerosene to concentrations determined according to preliminary tests. In the mixed sprays the concentration of acetone was so reduced that any effect on mortality was negligible. The mixed sprays were prepared only in the proportion of 5 parts of the sulfone to 1 part of the insecticide, as was done with the sulfoxide.

Knockdown and mortality were determined in replicated tests, in each of which approximately 96 flies averaging 2½ to 3½ days in age were used. All sprays were tested simultaneously on each of seven populations of flies. To evaluate relative toxicity and determine the precision of the estimates, the mortality data were subjected to probit analysis as described by Finney (1952).

Knockdown and Mortality Results.—The knockdown and mortality data are summarized in table 1. Three of the mixed allethrin sprays were the same in concentration of allethrin as three of the sprays containing the insecticide alone; the knockdown caused by the mixed sprays was about what would be expected of allethrin alone. The mixed pyrethrum sprays contained considerably less pyrethrins than the sprays containing that insecticide alone, and such a comparison could not be made. However, the knockdown caused by the mixed sprays was high even at the lower concentrations and, judging from previous experience, it differed little from what would be expected of pyrethrins alone.

Table 1.—Mortality and knockdown of house flies caused by kerosene sprays selected to compare the effects of a sulfone in pyrethrum and allethrin mixtures.[a]

Material	Concentration			Knockdown in 25 Minutes	Mortality in 1 Day
	Insecticide	Sulfone	Insecticide Equivalent[b]		
	Milligrams per deciliter			*Per Cent*	*Per Cent*
Sulfone	—	16,000	—	56	32.1
	—	8,000	—	22	19.5
	—	4,000	—	16	11.4
	—	2,000	—	4	7.2
Pyrethrins	745	—	745	100	93.8
	372	—	372	100	67.0
	186	—	186	100	35.3
	93.1	—	93.1	100	13.8
Pyrethrins +sulfone	50.0	250	52.33	100	96.1
	25.0	125	26.16	100	74.0
	12.5	62.5	13.08	99.8	22.4
	6.25	31.3	6.54	84	4.7
Allethrin	200	—	200	100	91.2
	100	—	100	100	63.9
	50.0	—	50.0	99.4	27.0
	25.0	—	25.0	93	5.8
Allethrin +sulfone	100	500	101.55	100	97.3
	50.0	250	50.78	100	72.1
	25.0	125	25.39	95	21.9
	12.5	62.5	12.69	80	7.4

[a] Seven replicates.
[b] Based on the relative toxicities of the sulfone as given in table 2.

Evaluation of Relative Toxicity.—To put the relationships on a quantitative basis, provisional regression lines were fitted graphically to the data in table 1. Weighted individual regression lines were computed by the maximum-likelihood method. No study of parallelism was made, it being deemed unnecessary for the purposes of this study; in fact it had not been the plan with such few concentrations. Rather, the concentrations of the sprays except those of the sulfone alone had been so selected that the means were very close to the median lethal concentrations (LC-50's) and any difference in slope of the fitted lines would have little effect on estimations of relative toxicity based on these concentrations. The data for the sulfone described only the lower portion of the toxicity curve.

The final equations of the lines showing the regression of mortality, expressed in probits, on concentration in milligrams per deciliter, expressed as logarithms, are given below. Those for the mixtures are based on the expression of concentration in terms of insecticide content only.

Sulfone (in part)	$Y=1.0408X+0.1071$
Pyrethrins	$Y=2.8287X-1.7452$
Pyrethrins+sulfone	$Y=3.9854X+0.0039$
Allethrin	$Y=3.2384X+1.1117$
Allethrin+sulfone	$Y=3.8171X-0.9127$

[1] Accepted for publication September 3, 1954.

Table 2.—Evaluation of relative effects in the toxic action of a sulfone in mixtures with pyrethrins and allethrin.

Material	LC-50 (Milligrams per Deciliter)		Relative Standard Error of LC-50 (Per Cent)	Ratio of Toxicity on Indicated Bases					Log of Ratio on Equivalent Basis to Proper Insecticide
				To Pyrethrins			To Allethrin		
	Original Basis	Insecticide Equivalent		Original	Insecticide Content	Insecticide Equivalent	Original	Insecticide Equivalent	
Pyrethrins	242.4	242.4	5.38	1.0	1.0	1.0	0.318	—	—
Pyrethrins +sulfone	17.93 +89.65	18.76	4.44	—	13.52	12.92	—	—	1.111
Allethrin	77.14	77.14	2.07	3.14	3.14	3.14	1.00	1.00	—
Allethrin +sulfone	35.41 +177.1	35.96	7.83	—	6.84	6.74	—	2.15	0.332
Sulfone	17,850[a]	—	22.7[a]	0.0093	—	—	0.0031	—	—
Minimum required to demonstrate synergism	—	—	—	—	—	1.15, 3.69[b]	—	1.18	0.061, 0.070[b]

[a] All estimations made at the 32 per cent mortality level instead of 50 per cent; LC-32 for pyrethrins is 165.7 and for allethrin is 55.31 mg. per deciliter.
[b] The first figure in each pair refers to the pyrethrins mixture the second to the allethrin mixture.

From the equations for the insecticides and the mixtures LC-50's were estimated and the relative toxicities were calculated as the inverse ratios of these estimations. The results are reported in table 2. Extrapolation from the determined portion of the curve for the sulfone to obtain an LC-50 would have little effect on the results for the mixtures because of its relatively low toxicity; in fact, estimations based on insecticide equivalents would simply approach more closely those based on insecticide content only. However, to avoid the implications regarding the undetermined portion of the curve made by such an extensive extrapolation, it was deemed preferable to make the estimations in the actual range studied and yet as near the 50 per cent mortality level as possible. Therefore, for estimations of the toxicity of the sulfone relative to the two insecticides, comparison was made at the 32 per cent mortality level, the LC-32 used being estimated from the equation rather than that of the single observed point. Either of these values may be used without material effect on the ratios of toxicity (and therefore on insecticide equivalents), but use of the equation permits a better assessment of error and, except for the mortality level, keeps the treatment of data uniform. The necessary estimations of the LC-32's for pyrethrins and allethrin were made from the equations for the two insecticides.

The evaluation of relative effects is also given in table 2. Relative toxicity was determined on the basis of insecticide equivalents and also on the basis of actual insecticide content. The former procedure is the proper one to demonstrate synergism and measure its intensity, although because of the relatively low toxicity of the sulfone there is no practical difference between the procedures in this study. The insecticide equivalent of a mixture is the sum of the actual amount of the insecticide and the insecticide equivalent of the adjunct. The latter is the product of the actual amount of adjunct and its toxicity relative to the insecticide. To demonstrate synergism a significant increase in toxicity of the mixture over that expected must be shown.

Estimates of the precision of the measurements were made. The standard errors of the regression coefficients, in the order in which the equations are given, were 0.190, 0.219, 0.296, 0.101, and 0.504. Heterogeneity factors used were, in the same order, 4.40, 5.49, 5.79, 1, and 17.53. The errors of the LC-50's, reported as relative standard errors, and the minimum requirements to demonstrate synergism, calculated from the standard errors, are also given in table 2. The evidence of synergism is pronounced in each mixture.

Discussion of Effects.—The mortality results show that the pyrethrins mixture is the better mixture and that both mixtures are considerably better than pyrethrins alone. The concentrations required to give approximately the same range in mortality are about twice as high for the allethrin mixture and about 15 times as high for pyrethrins alone as those required by the pyrethrins mixture. The precise quantitative relationships are expressed in table 2, where it is shown that the pyrethrins mixture is about 13 times and the allethrin mixture about 7 times as toxic as pyrethrins alone.

As also shown in table 2, the sulfone synergized pyrethrins much more powerfully than it did allethrin, the relative toxicity being 12.9 as much as the expected when pyrethrins was used in the mixture and only 2.2 when allethrin was used.

Had the mean of the observed portion of the regression line been chosen as giving the best information or the relative toxicity of the sulfone, there would have been no practical difference in results. The weighted, statistical mean was $\bar{x}=3.8262$, $\bar{y}=4.0846$, corresponding to 6,702 mg. per deciliter and 18 per cent mortality. From comparison with the LC-18's for pyrethrins and allethrin, 115.1 and 40.23 mg. per deciliter, respectively, the ratios of toxicity obtained are 0.0172 and 0.0060 as compared with 0.0093 and 0.0031 at the 32 per cent level as reported in table 2. If these be used as insecticide equivalents of the sulfone in the LC-50's of the mixtures, the ratios of toxicity on the equivalent basis of the proper insecticide are 12.45 and 2.12, which are very close to the 12.92 and 2.15 as reported in table 2. In fact, they are within experimental error.

These results with the sulfone, when compared with

similar estimations made previously by the same method with the sulfoxide as the synergist (Gersdorff *et al.* 1952), show that the two materials have about the same effects in mixture with these insecticides; there is no choice between them as synergists for pyrethrins or allethrin in house fly sprays. From the standpoint of chemical structure, the additional oxygen atom in the molecule of the sulfone therefore has little effect on synergistic action.

SUMMARY.—The comparative effect of a sulfone in oil sprays containing either allethrin or pyrethrins in the proportion of five times as much adjunct as insecticide was determined in tests against the house fly, *Musca domestica* L., by the turntable method.

The sulfone synergized both insecticides, pyrethrins much more powerfully than allethrin. The relative toxicity was 12.9 as much as expected in the mixture with pyrethrins and only 2.2 as much in the mixture with allethrin.

The relative effectiveness of the insecticidal materials was rated as follows, whether the evaluation was based on insecticide content only or on insecticide equivalent: pyrethrins (1), allethrin (3), allethrin plus the sulfone (7), and pyrethrins plus the sulfone (13).

Knockdown of flies was high in all sprays containing the insecticides. The sulfone alone caused relatively little knockdown and mortality.

REFERENCES CITED

Finney, D. J. 1952. Probit analysis, 318 pp. Cambridge.

Gersdorff, W. A., R. H. Nelson, and Norman Mitlin. 1952. Sulfoxide and 3,4-methylenedioxybenzyl *n*-propyl ether in pyrethrum and allethrin mixtures as house fly sprays. Jour. Econ. Ent. **45**(6): 905–8.

Starr, Donald F., and Charles DiSanto. 1953. A spectrophotometric method of assay for sulfoxide. Chem. Spec. Mfrs. Assoc., Proc. 40th Ann. Meet.; 153–4.

Synerholm, Martin E., Albert Hartzell, and Victor Cullmann. 1947. Pyrethrin extenders. Boyce Thompson Inst. Contrib. **15**(1): 35–45.

Field Tests for Control of Wireworms Attacking Corn[1]

WALTER M. KULASH and ROBERT J. MONROE,[2,3] *North Carolina Agricultural Experiment Station, Raleigh*

Wireworms are responsible for serious damage to corn in many sections of North Carolina, particularly in certain eastern counties with a peat muck type of soil where a 2-year rotation of oats, soybeans, and corn is the general practice. All stages of corn may be attacked. The period of greatest wireworm damage occurs shortly after planting when the seed becomes swollen and soft and may be so badly riddled that only fragments remain after an attack. As many as 10 wireworms have been found near one seed. Seedlings have their roots eaten or their stems tunneled, in effect being girdled. Injury continues until the plant is 24 or more inches high. The stem is tunneled and the roots may be eaten so badly that the plant has no support and falls over in a stiff breeze.

In cases of severe wireworm attack, the entire stand may be destroyed. Ordinarily, patches of 1 to 3 acres are destroyed. A survey made in Hyde County in 1950, in an area with a history of wireworm damage for the past several years, showed severe wireworm damage in over 60 per cent of the fields examined. Two-thirds of the total acreage of these fields was plowed under and replanted to other crops.

Most of the wireworm damage to corn in Hyde County and in adjacent counties was caused by three species of wireworms of which *Melanotus communis* (Gyll.) was the most abundant. *Conoderus lividus* (De G.) was commonly found in most areas where *M. communis* is present. Full-grown larvae of either of these species measure about 25 to 30 mm. long. The third species, *Glyphonyx recticollis* (Say), has full-grown larvae only 12–14 mm. long.

The heavy losses caused by wireworms and the low per acre value of crops grown in Hyde County presented a problem in determining an economical method for wireworm control. Laboratory and field trials with seed dressings have been reported (Kulash 1953). Preliminary tests with soil treatments and fertilizer-insecticide mixtures have also been reported (Kulash & Monroe 1954). This paper summarizes further field trials conducted in Hyde County where wireworm infestations were heavy. Preliminary field tests were made in 1950 and more extensive tests in 1951 and 1952.

METHODS OF APPLICATION.—Three basic methods of applying insecticides were used: (1) seed coating, (2) soil treatment with a spray or dust followed by disking of soil to a depth of 4 inches, and (3) mixing with fertilizer and applying the mixture to the drill row at the time of planting. In addition, certain combinations of these treatments were used.

In 1950, seed coatings were used with a sticker.[4] In some cases, "blackstrap" molasses was used as a sticker—the seed being first treated with the molasses and then mixed with the insecticide. Most of the seed coatings were made by hand mixing, but some were made with the help of a vibrating paint-reconditioning machine, which effected an even, smooth coating.

Soil applications in all tests were made with a small-grain drill in rows about 9 inches apart. The drill had a long narrow box, divided lengthwise into two compartments, one compartment for seed and the other for fertilizer—the latter being used in our tests for the insecticides. Granulated and dust formulations could be delivered with this type of machine at rates of 50 to almost 200 pounds per acre. Subsequent disking and cross-disking served to mix the soil and insecticide to the desired depth. The chief advantage of making soil applications

[1] Contribution from the Entomology Faculty, Division of Biological Sciences, N. C. Agricultural Experiment Station, Raleigh. Published with the approval of the Director of Research as Paper No. 512 of the Journal Series. Accepted for publication August 29, 1954.

[2] Associate Professors in Entomology and Statistics, respectively.

[3] Grateful acknowledgment is made to Mrs. H. F. (Anne) Howden, Mr. Byrd Dozier, and Mr. Marvin Swindell who assisted in various ways in this work.

[4] Prepared from Methocel, a 15 centipoise viscosity water-soluble cellulose ether supplied by the Dow Chemical Co., Midland, Mich.

with such a machine was that the insecticide was delivered directly into the soil, thus avoiding loss by drift.

The fertilizer-insecticide combinations were prepared from wettable powder concentrates in the laboratory at Raleigh. A fertilizer of 5–10–5 analysis was used for all of these mixtures.

DESCRIPTION OF FIELD TESTS.—The 1950 tests were conducted in an area where it was estimated that 50 per cent of the 1949 stand of corn had been destroyed by larvae of *Melanotus communis*. Some hills of corn, up to 24 inches tall, had as many as 40 wireworms feeding in or on the roots, providing a good locale in which to check the performance of various materials applied in different ways.

The three basic methods of application were used in the 1950 tests. In addition, combinations of these methods were used including (a) treated seed and treated soil, (b) treated seed with treated soil and fertilizer-insecticide mixture, and (c) treated soil and fertilizer-insecticide mixture. Seed was treated a few days before planting. Soil treatments with DDT, chlordane, and heptachlor were made in November, 1949, or on April 4, 1950—a few days before planting. One plot received two treatments with chlordane—first in November, 1949, and again in April, 1950, before planting. Combination treatments with DDT, chlordane, heptachlor, and parathion were also applied. The size of the 1950 test plots varied from 2 to 8 rows in width and were 900 feet long. Corn was planted on April 9 with a tractor-drawn planter at a drill spacing of about 8 to 10 inches in rows 3.5 feet apart. An open pollinated corn, Wood's Yellow, commonly grown in Hyde County, was used in all tests each year.

The 1951 tests were conducted in a field that had considerable wireworm damage to the corn grown there in 1949. Pre-treatment sampling in 1951 showed that of the three aforementioned species present, the most abundant was *Melanatus communis*. The three basic methods of application were used. In addition, four combinations of these applications were used including the three combination methods tried in 1950. The fourth combination method was treated seed and fertilizer-insecticide mixture. Plots were five rows wide and 12 feet long. Rows were spaced 3.5 feet apart. Corn was planted by hand on April 6, 1951, at a spacing of 6 inches in the row. A foot of row on either end of each plot was left unplanted, thus each row received 20 seeds and each plot, 100 seeds. Each method of treatment was located at random for each material used. The following materials were located at random within each of four blocks:[4] aldrin, chlordane, dieldrin, heptachlor, and lindane. All applications were made just before planting. Soil treatments were made with granulated dust[5] formulations (30 to 60 mesh) at the rate of 400 pounds per acre of finished formulation containing the specified amount of toxicant. The insecticides were worked into the top 4 inches of soil. Fertilizer-insecticide mixtures were applied to the drill row just before planting at the rate of 350 pounds of fertilizer per acre containing the specified amount of toxicant. In the combination treatments, the soil was treated first and then the fertilizer-insecticide mixture was applied to the drill row.

The 1951 test area was again planted to corn in 1952. Two blocks were planted to lindane-treated seed and two blocks to untreated seed.

Field tests were conducted in 1952 in an area, adjacent to the 1951 test area, that had been planted to oats and lespedeza in 1951. Pretreatment sampling showed wireworms to be abundant in this area. The 1952 plots were four rows wide and 25 feet long. Corn was planted by hand at a spacing of 12 inches in rows 3.5 feet apart. Methods of application and treatments were randomized as in 1951. Aldrin, dieldrin, EPN, heptachlor, lindane, and Systox were used. Four methods of application were used: (1) seed coating, (2) soil treatment, (3) fertilizer-insecticide mixtures, and (4) combination of soil treatment and fertilizer-insecticide. Soil treatments were made just before planting and 8 weeks later, with sprays formulated from emulsion concentrates. The fertilizer-insecticide mixtures were applied in the furrow at the time of planting.

EVALUATION OF RESULTS.—The principal method of checking the results of the various tests was based on a system of plant counts at intervals during the early stages of growth. In the preliminary tests of 1950, counts were made of the number of damaged seeds and the number of wireworms in 10 seeds at 10 days after planting. In addition, the percentage of the stand at 6 weeks after planting was estimated on the basis of counts of plants in samples of 50 feet of row. In 1951, the plant counts were made in 10 feet of row in the center row of each plot. In 1952, plants in 10 feet of row in the second and third rows of

Table 1.—Seed coating trials for wireworm control. 1950.

Insecticide[a]	Number in 10 Hills of Corn 10 Days After Planting: Wireworms Alive	Wireworms Dead	Wireworm-damaged Seeds	Estimated Stand (Per Cent) 6 Weeks After Planting
DDT 50%	22	0	8	0
Parathion 15%	7	7	2	70
Heptachlor 25%	15	3	6	70
Lindane 25%	5	0	1	60
Chlordane 25%			0	40
Untreated	27	0	8	0

[a] Wettable powder formulations used at rate of 4.56 grams to 450 grams of seed.

[4] Inert attapulgite supplied by the Attapulgus Clay Co., Philadelphia, Pa.

Table 2.—Soil-treatment tests for wireworm control. 1950.

Insecticide (Dust)	Pounds per Acre Applied: Nov. 4, 1949	Apr. 7, 1950	Number in 10 Hills of Corn 10 Days After Planting: Wireworms	Wireworm-damaged Seeds	Estimated Stand (Per Cent) 6 Weeks After Planting
Chlordane 10%	50	75	1	2	79
Chlordane 10%		75	9	3	0
DDT 10%	50		29	8	0
DDT 50%		75	12	3	0
Heptachlor 5%		100	3	1	90
Untreated	0	0	27	8	0

Table 3.—Combination treatments for wireworm control. 1950.

Materials Used		Pounds per Acre Applied		Number in 10 Hills of Corn 10 Days After Planting			Estimated Stand (Per Cent) 6 Weeks After Planting
				Wireworms		Wireworm-damaged Seed	
On Seed[a]	On Soil[b]	Nov. 1949	April, 1950	Alive	Dead		
Chlordane 50%	Chlordane 10%	50	75	2	1	2	60
DDT 50%	DDT 10%	50		21	0	8	0
Heptachlor 25%	Heptachlor 5%		100	1	0	1	90
Parathion 15%	Chlordane 10%	50	75	6	0	2	85
Untreated	Untreated	0	0	27	0	8	8

[a] 4.56 grams of indicated wettable powder formulations per 450 grams of seed.
[b] Dust formulations used.

each plot were counted. Thus, a perfect stand in a unit sample per plot in either year was 20 plants.

In 1951, in addition to the plant counts, a series of soil samples were taken before and after treatment in order to determine the relative abundance of the different species of wireworms. Two soil samples per plot were dug 4 inches in diameter to a depth of 6 inches, put into gallon-size tin cans and brought into the laboratory where they were sifted through a 14-mesh wire screen cloth for examination.

Results of 1950 Tests.—A summary of the wireworm abundance and damage to seed in the 1950 tests is presented in tables 1 to 4, inclusive. Field observations indicated severe injury in several plots. On the basis of counts of seed and stand, it was quite apparent that seed coating, under the conditions of this test, did not provide ample protection against wireworm attack. Seed treated with DDT (Table 1) was severely attacked and had almost as many wireworms as untreated seeds. Plots with lindane-treated seed had few wireworms 10 days after planting but counts 6 weeks after planting indicated only a 60 per cent stand. Although wireworms were abundant at 10 days after planting in plots having the seed treated with heptachlor or parathion, nevertheless, these plots had a 70 per cent stand 6 weeks after planting. Dead wireworms were found near seeds treated with parathion or heptachlor but not in the other treatments. A poor stand was obtained with the chlordane-treated seed.

Soil treatments (Table 2) with 75 pounds per acre of 50 per cent DDT or 75 pounds per acre of 10 per cent chlordane dust applied just before planting were ineffective. Soil treated twice with chlordane, first in November, 1949, at 50 pounds of 10 per cent dust per acre and again in April, 1950, (just before planting) at 75 pounds of 10 per cent dust per acre had a moderately good stand. The best stand was obtained in the heptachlor treatment at 100 pounds of 5 per cent dust per acre applied in April, 1950, just before planting.

Combination treatments of seed and soil with DDT or chlordane did not appear any more effective than either treatment by itself. In the case of chlordane, the plot with the combination treatment had a 60 per cent stand remaining 6 weeks after planting (Table 3) whereas the plot with soil treatment alone had a 79 per cent stand (Table 2). Part of this difference may have been due to wet soil conditions in the plots receiving the combination treatment. The heptachlor soil treatment was superior to the seed treatment but the combination treatment was no more effective than the soil treatment by itself (Tables 2 and 3).

The original soil treatment with DDT in the 1950 tests did not prevent severe wireworm damage. These soil-treated plots were replanted with treated seed about 2 weeks after the original planting date when the first stand had been destroyed by wireworms. Plots planted with seed treated with dieldrin or chlordane had the best stand 6 weeks after planting (Table 4) but these results cannot be compared directly with the other seed-treatment tests made in 1950 because of differences in date of planting and in soil treatment before planting.

Results of 1951 Tests.—The effectiveness of the various treatments were judged chiefly on the condition of the stand at various times throughout the growing season. In addition to stand counts, an attempt was made

Table 4.—Results of replanting with treated seed after first planting of corn had been destroyed in soil treated with DDT. 1950.

Seed Treatment of Replanted Corn[a]	Original Soil Treatment with DDT			Number in Hills of Corn 10 Days After Planting		Estimated Stand (Per Cent) 6 Weeks After Planting
	Formulation Used	Pounds per Acre		Wireworms	Wireworm-damaged Seed	
		Nov., 1949	Apr., 1950			
Dieldrin 25%	DDT 50%		75	0	0	85
Chlordane 50%	DDT 10%	50		0	0	70
Parathion 15%	DDT 10%	50		0	0	58
Lindane 25%	DDT 10%	50		1	1	51
Untreated	Untreated			20	7	0

[a] 4.56 grams of indicated wettable powder formulations per 450 grams of seed.

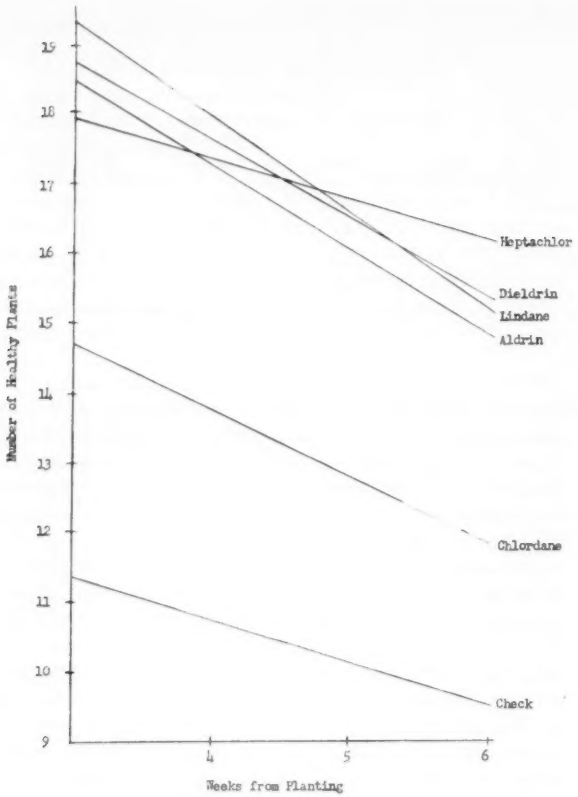


FIG. 1.—Average decrease in number of healthy plants in 1951 tests on basis of materials used.

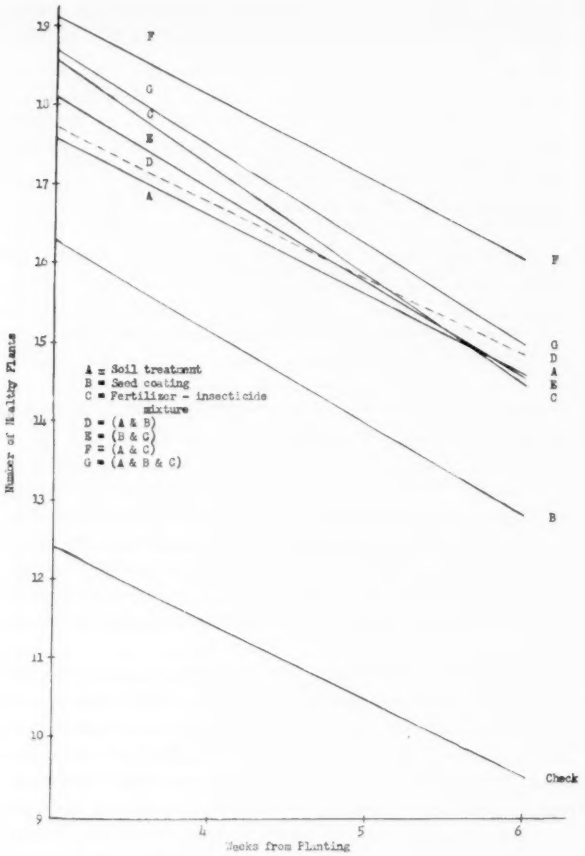

Number of Healthy Plants
Weeks from Planting
A = Soil treatment
B = Seed coating
C = Fertilizer - insecticide mixture
D = (A & B)
E = (B & C)
F = (A & C)
G = (A & B & C)
Check

FIG. 2.—Average decrease in number of healthy plants in 1951 tests on basis of methods of treatments.

to determine the abundance of wireworms before treatment, during and after the growing season.

Plant counts were made at 8 weekly intervals starting on April 25 (18 days after planting) and ending on June 15. The first and second counts were not used in evaluating the results in order to avoid attributing to wireworm damage differences in number of plants that may have been caused by lateness in germination or damage that may have been caused by early cultivation. The seventh and eighth plant counts were made after stands had been thinned and, likewise, were not used in evaluating results. Each plant count was made in the third row of each plot. The total number of healthy and damaged plants in the entire row was noted. In addition, all damaged plants were dug and the nature of the wireworm damage was noted—whether it occurred in the seed or in the stem. The soil within a 3-inch radius of the plant to a depth of 6 inches was sifted and the dead and live wireworms were noted. The principal criterion of the effect of insecticides and methods of application was based on the plant counts. In this analysis, the rate at which the number of

Table 5.—Methods and materials used in 1951 wireworm control tests.

Materials	Methods of Treatment						
	A[a] Soil Treatment	B[b] Seed Coating (Grams Used)	C[a] Fertilizer-insecticide Mixture	D Methods A+B	E Methods B+C	F Methods A+C	G Methods A+B+C
Aldrin	1	22.8[b]	1	1—22.8	22.8—1	1—1	1—22.8—1
Chlordane	5	45.6	5	5—45.6	45.6—5	5—5	5—45.6—5
Dieldrin	2	45.6	2	2—45.6	45.6—2	2—2	2—45.6—2
Heptachlor	2	45.6	2	2—45.6	45.6—2	2—2	2—45.6—2
Lindane	2	22.8	2	2—22.8	22.8—2	2—2	2—22.8—2
Check	0	0	fertilizer only	0—0	0—0	0—0	0—0 —0

[a] Figures listed refer to pounds of toxicant per acre.
[b] Number of grams of 25 per cent wettable powder concentrate used per acre planting of corn seed except for chlordane which was used as a 50 per cent wettable powder. Wettable powder applied at 2.28 grams or 4.56 grams per pound of seed and seed planted at rate of 10 pounds per acre.

healthy plants decreased as well as the average number of healthy plants were both considered.

For the 35 treatment combinations of materials and methods of application, listed in table 5, a linear regression line was fitted to each replication over the 4 weeks (i.e., counts 3 to 6 inclusive, the period of greatest wireworm activity) and the linear regression coefficients were analyzed. The analysis indicated that significant differences existed among the materials in the rate of decrease of healthy plants but that differences among methods could reasonably be ascribed to chance. There was no evidence that these regression coefficients were affected by any differential effects of methods or materials. The largest difference was observed in heptachlor which had the lowest rate of decrease of healthy plants. All the other materials seemed to show about the same rate of decrease in number of healthy plants.

The rate of decrease in the untreated plots was not appreciably different from the treated plots, with the exception of the heptachlor-treated plots. The rate of decrease is shown for materials in table 6 and in figure 1, and for methods in figure 2.

An analysis of variance of the average number of healthy plants indicated marked differences in the general level due to materials and somewhat less positive evidence of differences due to methods. There was little or no evidence that the materials reacted differently under the various methods of application. All treated plots were protected to some extent when compared with the untreated checks. Chlordane was least effective; all others about equally effective. Of the several methods there appears to be little choice with the exception of seed coating (Method B) which was substantially less effective than the others.

The mean number of healthy plants for methods and materials is given in table 7. In summarizing the 10-foot plant counts made at weekly intervals from 3 to 6 weeks after planting, it is apparent that all materials initially gave some protection. Heptachlor showed a higher degree of effectiveness than any of the other materials over this 3-week period. In the early part of the growing period, chlordane, amongst the materials, and seed coating, amongst the methods, gave only slight protection.

Another evaluation of the effectiveness of the various materials and methods of the 1951 tests was based on a combination soil and plant examination made on two different dates, May 16, and May 2. Two samples of row, 2.5 feet long, were examined in each plot on each date. The number of plants in each sample and those wireworm-damaged were noted. In addition, the entire 2.5-foot section of row was then dug 6 inches deep and 6 inches wide and the soil was screened to determine the number of wireworms present. The May 2 counts were made in the second row of each plot and the May 16 counts, in the fourth row and the results are presented in table 8.

Table 6.—Mean decrease in number of healthy plants in 10 linear feet of row in a 3-week period at 4 to 6 weeks after planting[a] in wireworm tests. 1951.

Lindane	2.15
Chlordane	1.96
Aldrin	1.77
Dieldrin	1.67
Heptachlor	0.92
Check	1.45
L.S.D. (5%)	0.72 (except check) 0.93 (including check)

[a] Wireworm damage was at its peak during this period.

Table 7.—Mean number of healthy plants in 10 linear feet of row in a 3-week period at 4 to 6 weeks after planting in 1951 wireworm tests.

By Materials[a]		By Methods[a]	
Lindane	17.21	F = (Methods A & C)	17.54
Heptachlor	16.96	G = (Methods A & B & C)	16.79
Dieldrin	16.94	C = (Fertilizer-Insecticide mixture)	16.50
Aldrin	16.55	E = (Methods B & C)	16.30
Chlordane	13.73	D = (Methods A & B)	16.24
L.S.D. (5%) among materials,	2.83	A = (Soil treatment)	16.06
		B = (Seed treatment)	14.52
		L.S.D. (5%), among methods,	1.64
Check	10.92	Check	10.92
L.S.D. (5%) Check vs. other materials	3.65	L.S.D. (5%), Check vs. other methods,	1.89

[a] Perfect stand = 20 plants in 10 feet of row.

In general, these combination soil and plant examinations showed about the same results as the weekly plant counts, already described. The total number of wireworms for all treated plots increased markedly between the first and second counts in 1951. For materials, the average number of wireworms in the first count was 83 and in the second, 149, whereas the checks had 93 and 122 wireworms, respectively, on these two dates. There was no appreciable difference in the number of dead wireworms amongst the different treatments. The percentage of plants injured in the second count in 1951 was nearly double that in the first count. Lindane had the least increase in percentage of plants damaged, 10, and the check had the greatest, 43. For methods, the least percentage increase in damaged plants was noted in the fertilizer-insecticide treatment, 7 per cent, and the untreated checks showed the greatest increase, 32 per cent. Despite the increase in the number of wireworms and the number of plants injured between the first and second counts, the total number of plants in these two counts was about the same—1,041 for the first count and 1,020 for the second.

Early injury to corn by wireworms was confined to the seed. As the plants grew, the proportion of seed and stem damage began to change. In the combination soil and plant examinations of May 2, an average of 61 per cent of the damage to corn was to the seed but in the May 16

Table 8.—Comparison of two combination soil and plant examinations made in corn grown in 1951 test area in 1951 and in 1952.

Year	Treatment[a]	Total Number: Wireworms: Count 1[b]	Total Number: Wireworms: Count 2	Total Number: Plants: Count 1	Total Number: Plants: Count 2	Plants Injured (Per Cent): Count 1	Plants Injured (Per Cent): Count 2
1951	Treated	416	746	1041	1020	14	26
	Check	93	122	146	147	24	57
1952	Treated	212	324	1320	1334	9	1
	Check	102	77	237	252	12	3

[a] Number of treated plots, 140; check plots, 20.
[b] In 1951, count 1 made on May 2 and count 2 on May 16.
In 1952, count 1 made on May 23 and count 2 on June 3.

Table 9.—Comparison of seed-treated vs. untreated seed blocks of corn grown in 1952 in the 1951 test area.

	Total Number				Plants Injured (Per Cent)	
	Wireworms		Plants			
	Count 1	Count 2	Count 1	Count 2	Count 1	Count 2
Seed-treated	112	95	686	730	4	1
Untreated	110	229	634	604	16	1

examinations only 50 per cent occurred there. The weekly plant counts of May 2 to May 30 further corroborated this evidence in regard to type of injury. On May 2, the plant counts showed about 50 per cent seed injury but on May 15, only 6 per cent of the damage was to seed. The ratio of seed to stem damage appeared to be more pronounced in the weekly plant counts than in the combination soil and plant examinations of May 2 and 16. It should be recalled, in this regard, that all plants were dug in the combination 2.5-foot samples but only the wilted plants were dug and compared as to seed and stem injury in the weekly 10-foot samples. It may thus have been possible to miss wireworm injury which had not begun to show up as noticeable wilting or discoloration of the foliage.

Observations on Corn Grown in 1952 in the 1951 Test Area.—The 1951 test area was hand-planted to corn in 1952 at a 6-inch spacing in the drill row without any additional treatment except that two blocks were planted with seed treated with $2\frac{2}{3}$ ounces of 75 per cent lindane wettable powder, to 1 bushel of corn and two blocks were planted to untreated seed. The purpose of replanting with treated and untreated seed was to determine (1) any residual effect of the 1951 treatments on corn grown in 1952 and (2) any effect obtained by treating seed.

Results of the 1952 planting in the 1951 test area were based on plant counts and combination soil and plant examinations made in the same manner as described for the evaluation of the 1951 tests. Three plant counts were made at 10-day intervals and showed only a slight difference in stand per unit sample amongst the various materials or methods of treatment. Plants in untreated check plots were almost equal in number to those in treated plots. The decrease in number of plants between the first count and the third was not very marked. The corresponding increase in number of injured plants was more noticeable during this period, but this increase was about the same whether the seed had been treated or not. The plant count alone did not afford a good criterion for evaluating differences that might have occurred. The combination plant and soil examinations made on two different dates seemed to be a better means of evaluating these differences. A summary comparing these plantings based on the total number of wireworms, the total number of plants, and percentage of plants damaged, is presented in table 8. The percentage of plants damaged and

Table 10.—Results of pre- and post-treatment soil samplings in 1951 test area.

	Wireworms[a] Collected in Pre-Treatment Sampling				Wireworms Collected in Post-Treatment Sampling							
	March, 1951				Jan., 1952				Nov., 1952			
By Materials	*C*	*G*	*M*	Total	*C*	*G*	*M*	Total	*C*	*G*	*M*	Total
Aldrin	0	6	0	6	5	12	5	22	2	21	2	25
Chlordane	0	1	2	3	6	6	3	15	5	10	2	17
Dieldrin	0	0	1	1	4	6	0	10	6	7	2	15
Heptachlor	0	4	3	7	2	6	0	8	6	9	0	15
Lindane	2	4	5	11	1	8	4	13	5	19	0	24
Total	2	15	11	28	18	38	12	68	24	66	6	96
Untreated	0	3	0	3	3	0	3	6	3	8	0	11
By Methods												
A (Soil treat.)	0	0	0	0	5	6	3	14	3	14	1	18
B (Seed coating)	1	0	0	1	4	16	2	22	2	16	1	19
C (Fert.-Ins. Mix.)	0	2	4	6	3	0	0	3	3	13	0	16
D (A & B)	1	6	0	7	6	3	3	12	6	7	1	14
E (B & C)	0	2	1	3	0	7	0	7	4	7	1	12
F (A & C)	0	1	4	5	0	5	2	7	1	0	1	2
G (A & B & C)	0	4	2	6	0	1	2	3	5	9	1	15
Total	2	15	11	28	18	38	12	68	24	66	6	96
Untreated	0	3	0	3	3	0	3	6	3	8	0	11
Total by Dates												
Pre-treatment March 1951	2	5	11	28								
Post-treatment January, 1952	18	38	12	68								
Post-treatment November, 1952	24	66	6	96								

[a] C = *Conoderus lividus*; G = *Glyphonyx recticollis*; M = *Melanotus communis*.

the average number of wireworms was much higher in 1951 than in 1952. Furthermore, in 1951, damage and number of wireworms increased between the first count and the second in both treated and untreated plots. In 1952, damage decreased between the first and second counts and number of wireworms increased in the treated plots but decreased in the check plots.

The 1952 plantings were further compared with regard to the use of treated versus untreated seed and the results are given in table 9. Blocks planted with treated seed had about the same number of wireworms as those planted with untreated seed at the first count but at the second count, the untreated seed had more than twice as many wireworms. There were more plants in the treated blocks than in the untreated at both counts, but injury was much more evident at the first count in the untreated blocks; at the second count, both treated and untreated blocks had only 1 per cent of the plant injured.

SOIL SAMPLING IN 1951 TEST AREA.—The relative abundance of the various species of wireworms in the 1951 test area was determined before and after treatment by taking soil samples as described previously, (1) in March, 1951—1 month before treatment and planting; (2) in January, 1952—2 months after harvest; and (3) in November, 1952—just after the second-year corn had been harvested. The pre-treatment sampling was done after the field had been plowed and disked preparatory to planting but before the rows had been run. Consequently, these samples were taken at random within each plot without regard to where the row of the previous crop had been. The two post-treatment samples were taken at random but in the row. Two samples were taken in each plot on each date. The results are summarized in table 10.

The first post-treatment samples had more wireworms than the pretreatment samples. This increase, for the most part, was due to an increase in the number of larvae of *Glyphonyx recticollis* which is thought to have a one-year life cycle and may have reinfested the test area in the summer of 1951 and 1952. The increase in numbers of *Conoderus lividus* in the post-treatment samples was not as marked as it was for *G. recticollis*. Larvae of *Melanotus communis* were just about as abundant in the first post-treatment samples as they were in the pre-treatment samples. The second post-treatment samples, however, had only one-half as many of these larvae as the first.

In general, the combination treatments had fewer wireworms in the post-treatment samples than the seed, soil, or fertilizer-insecticide treatments alone. Fewer wireworms were found in the untreated plots, or those treated with hepatchlor or dieldrin than in the plots treated with aldrin, lindane, or chlordane.

RESULTS OF THE 1952 TEST.—Evaluation of the effectiveness of the 1952 treatments as listed in table 11 was based primarily on three plant counts made at 10-day intervals beginning May 8. The first count showed poor germination. The total number of seeds planted (exclusive of untreated check plots) was 2880 but only 1618 plants were recorded. Of these, only 72 had been injured by wireworms. At the third count, the total number of plants was 1116 and of these 436 were damaged by wireworms.

Results of the third count, made on May 29, were used in the final evaluation of the effectiveness of the various insecticides and methods of treatment and are presented in table 12. The most effective insecticides, based on the stand remaining 6 weeks after planting, were dieldrin and heptachlor (33 per cent) and lindane (32 per cent). The untreated check had a 7 per cent stand. The best method of treatment was the combination of soil treatment at planting wlth fertilizer-insecticide at planting (Method F) which had a 40 per cent stand. The fertilizer-insecticide method of treatment (Method D) was next best with a 38 per cent stand.

COMPARISON OF 1951 AND 1952 FIELD TESTS.—This comparison on the basis of plant stands is presented in table 13. It should be remembered that in the 1951 test, corn was planted at a 6-inch spacing in the row, whereas in the 1952 test it was planted at a 12-inch spacing. In table 13 the figures represent the total number of plants for four replicates of any given material by all methods ("By Materials") or for all materials under any given method (By Methods"). In either case, in either year, a perfect stand would be 80 plants.

The most obvious difference to be noted between the results of the 2 years is in the number of plants in the ini-

Table 11.—Materials and methods used in 1952 field tests for wireworm control.

Materials Used	Pounds of Active Ingredient Per Acre in Method[a] Indicated					Grams of Indicated Per Cent Wettable Powder per 450 Grams of Seed (Method C)
	A	B	D[b]	E	F	
Aldrin	2	2	2	4	4	25%—4.46
Dieldrin	2	2	2	4	4	25%—4.46
Heptachlor	2	2	2	4	4	25%—4.46
Lindane	2	2	2	4	4	25%—2.28
Systox	4	4	4	8	8	50%—4.56
	A	B	C	D	E	
EPN	4	4	8	8	4	25%—4.56 (Method F)

[a] Methods (for all material except EPN)
A—Early soil treatment, about 8 weeks before planting.
B—Soil treatment at time of planting in early April.
C—Seed coating with wettable powder concentrates.
D—Fertilizer-insecticide applied in drill row at time of planting.
E—Method A and D.
F—Method B and D.
G—Untreated check.
Methods—for EPN only
A—Soil treatment, early, 4 lbs./A.
B—Soil treatment at planting, 4 lbs./A.
C—Soil treatment early, 8 lbs./A.
D—Soil treatment late, 8 lbs./A.
E—Fertilizer-insecticide at time of planting, 4 lbs./A.
F—Seed coat, 25% w.p. at 4.56 gms./450 grams seed.
G—Untreated check.

[b] Based on 3.5 foot wide rows and a total of 12,446.6 lineal feet of row per acre.

Table 12.—Original stand of 1952 test plots undamaged by wireworms 6 weeks after planting (third plant count).

Method of Treatment[a]	Stand Not Damaged by Wireworms (Per Cent)	Insecticides Used	Stand Not Damaged by Wireworms[b] (Per Cent)
F	40	Heptachlor	33
D	38	Dieldrin	33
E	37	Lindane	32
A	25	Aldrin	28
C	18	EPN	20
B	13	Demeton	16
Check	8	Untreated	7

[a] See table 11 for description of tests. Percentage given is for all materials (except EPN) according to method listed.

[b] Percentage for all methods according to materials listed.

Table 13.—Comparison of 2 years' field tests for control of wireworms attacking corn based on plant counts.

Materials[a]		No. of Healthy Plants in Count Number		
		1	2	3
Aldrin	1951	73	64	53
	1952	43	30	22
Chlordane	1951	61	54	41
Demeton	1952	46	29	13
Dieldrin	1951	74	65	58
	1952	43	29	26
EPN	1952	36	21	16
Heptachlor	1951	72	69	61
	1952	44	24	26
Lindane	1951	77	67	54
	1952	46	33	26
Check	1951	50	41	24
	1952	36	16	7
Methods[a,b]				
Broadcast	1951	67	62	52
Broadcast early	1952	43	30	20
late	1952	41	21	11
Seedcoating	1951	65	56	45
	1952	42	22	14
Insecticide-Fertilizer	1951	69	66	51
	1952	45	37	30
Broadcast and Insecticide-Fertilizer	1951	76	70	59
Broadcast early+Insecticide Fertilizer	1952	76	34	29
Broadcast late+Insecticide Fertilizer	1952	51	40	32
Broadcast+Seed Coating	1951	71	64	55
Seed Coating & Insecticide-Fertilizer	1951	74	62	56
Broadcast, Seed Coating & Insecticide-Fertilizer	1951	80	65	57
Check	1951	50	41	24
	1952	36	16	7

[a] The figures listed represent the number of healthy plants in 4 replicates for each treatment or material. In either year a perfect stand for four replicates at each plant count would be 80 plants.
[b] Does not include EPN.

tial count. In nearly all instances, there were more plants at the third count in 1951 than at the first count in 1952. In 1951, the average number of plants for all materials at the third count was 51, whereas at the first count in 1952 the average was 43. The average for the third count in 1952 was 22—less than half that of the 1951 test.

The lower number of plants in 1952 no doubt resulted from greater wireworm activity in the test area than occurred there in 1951. No direct comparison of wireworm populations in these two areas was made. However, the intensity of wireworm attack in the 1952 test was evident much earlier than it had been in the 1951 test. The total number of plants under "By Materials" or "By Methods" in the first counts of the two tests (Table 13) shows marked differences between the 2 years.

In 1951, the best stand was obtained in the heptachlor-treated plots. In regard to method of treatment, the best stand was obtained in the combination of the soil and of the fertilizer-insecticide mixture treatment. Treating the seed in this combination treatment did not improve the stand.

In the 1952 test, plots treated with dieldrin, heptachlor, or lindane each had a total of 26 plants. The combination method of treatment of soil at time of planting plus fertilizer-insecticide in the row at planting had the best stand, 32 plants, and fertilizer-insecticide in the row by itself had the next best stand, 30 plants.

Results of the 1951 and 1952 tests appear to be rather consistent, despite the difference in intensity of wireworm attack. Seed coating offered the least protection to corn in the 1951 test and only the untreated check was more injured in 1952. The combination of soil treatment and fertilizer-insecticide mixture applied in the row at the time of planting produced the best stand each year. Heptachlor, lindane, and dieldrin appeared to give the best results each year, based on stand counts.

Summary.—In eastern North Carolina corn is attacked by several species of wireworms. The more abundant species in Hyde County are: *Melanotus communis* (Gyll.), *Conoderus lividus* (De G.), and *Glyphonyx recticollis* (Say), of which *M. communis* was the principal wireworm involved in most of these studies.

Wireworms fed on ungerminated seed and, if such feeding was extensive, prevented germination. They fed on seed until the corn was 6 to 10 inches high when they began to feed on the stem. Seed dressings offered some initial protection against attack but were less effective as the plant grew older.

Results of testing with various methods of treatment with different insecticides during 1950–1952 showed that seed treatment was not as effective in protecting corn against wireworm attack as were other methods. In 1950, seed treated with heptachlor, had an estimated stand of 70 per cent 6 weeks after planting, whereas a soil treatment with heptachlor had 90 per cent. A combination treatment of seed and soil with heptachlor gave a 90 per cent stand.

In 1950, soil treatment with 5 pounds of DDT per acre, 4 months before planting, or 37.5 pounds of DDT per acre just before planting was ineffective. Chlordane at 7.5 pounds per acre applied just before planting was ineffective but was effective if applied at 5 pounds per acre 4 months before planting followed by 7.5 pounds per acre just before planting. The best soil treatment in 1950 was 5 pounds per acre of heptachlor applied just before planting.

In 1951, the combination method of treated soil and fertilizer-insecticide mixture applied in the row at time of planting appeared to be the most effective method of seven methods tried. The next best method was a combination of treated seed, soil, and fertilizer-insecticide. Next in order were the soil treatment alone, followed by the fertilizer-insecticide mixture alone. Of the materials used, heptachlor gave the best results, followed by lindane, dieldrin, aldrin, and chlordane in that order.

Two of the 1951 test blocks were planted in 1952 with

seed treated with lindane and two were planted with untreated seed. The seed-treated blocks had the more healthy plants and the fewer wireworms.

In 1952, the combination treatment of treated soil and fertilizer-insecticide mixture applied in the row at time of planting again appeared to be the best method of treatment followed by the fertilizer-insecticide method of treatment alone. Of the materials, dieldrin, heptachlor, aldrin, and lindane gave the best results in that order. EPN and demeton were not effective in these tests.

REFERENCES CITED

Kulash, W. M. 1953. Insecticidally treated seed for wireworm control. Jour. Econ. Ent. **46**(3): 433–41.

Kulash, W. M., and R. J. Monroe. 1954. Laboratory tests for control of wireworms. Jour. Econ. Ent. **47**(2): 341–5.

Dispersion of Radioactively Tagged *Drosophila* from Pit Privies[1]

DAVID PIMENTEL and R. W. FAY

Enormous numbers of *Drosophila melanogaster* and *D. repleta* have been observed in pit privies in the Rio Grande area of Texas. This high incidence of *Drosophila* in pit privies, their ability to enter homes in spite of good screening, and their habit of walking and feeding on fresh fruits and vegetables which may be eaten raw without washing suggest they might be important as potential vectors of disease (Maier & Pimentel).[2] For this reason studies were made in April and May, 1951, at Edcouch and Pharr, Texas, to determine the extent of *Drosophila* movement between pit privies and houses.

TECHNIQUE.—To determine adequate methods of tagging *Drosophila* with radioisotopes, groups of 25 adult *D. melanogaster* of each sex were offered 10-gram portions of fresh banana-yeast bait containing 20 microcuries of phosphorus-32 as $NaH_2P^{32}O_4$ for a 24-hour period. Males showed radioactivity levels from 20 to 260 counts per minute, females from 240 to 2100 c.p.m. Counts were made at $\frac{1}{4}$ inch from the flies with a Tracer Lab Monitor,[3] Model SU3A having an end window of 3 mg. per sq. cm. thickness. After 3 days few males were detectable but females showed levels of 235 to 1350 c.p.m.

Baits with P^{32} in (a) fermenting applesauce-vinegar mash and (b) stale beer were also satisfactory. Nonfermenting baits fed at short exposures of 1 to 8 hours were unsatisfactory whereas with the fermenting baits complete tagging of the flies was obtained within 2 to 4 hours. Concentrations of 1 to 2 microcuries of P^{32} per gram of bait were necessary for adequate tagging.

In field studies, treated baits were prepared using 50 grams of overripe ground banana, 10 milliliters of water, and 125 microcuries of P^{32} added as $NaH_2P^{32}O_4$. The P^{32} solution was pipetted over the surface of the banana-water mixture contained in a 4-ounce salve tin. Test flies were caught using as traps wide-mouth Mason jars, each containing two banana peels.

RESULTS.—To determine if *Drosophila* actually moved from pit privies to houses, 10 privies containing large *Drosophila* populations were selected in two adjoining blocks in the Latin section of Edcouch, Texas. These privies were 10 to 40 feet away from the adjoining houses. Between 4 and 5 P.M. one afternoon, two radioactive baits were suspended approximately 3 inches above the feces in each privy. Two baited jars, placed in each house, were used to trap adult flies during three periods, (1) from 5 P.M. to 8 A.M. on the first night, (2) from 8 A.M. to 5 P.M. the following day, and (3) from 5 P.M. to 8 A.M. on the second night.

The total *Drosophila* and the marked specimens recovered in each trap were tabulated under 10-power magnification. The marked flies were separated into two groups, (1) *D. melanogaster* and (2) *D. repleta*. The majority of the test privies contained mostly *D. repleta*.

The first night catches, checked only for radioactive flies in the traps, showed marked *Drosophila* in traps from 8 of the 10 houses (Table 1). Marked *Drosophila* were found in only 2 of the 10 houses during the day trapping period. During the second overnight trapping period, marked flies were trapped in 7 of the 10 houses. Thus the total number of flies collected during the overnight trapping periods was much greater than in the daytime. The ratio of marked to unmarked flies collected at night was lower than that for flies collected in daytime. Sex determinations on 1234 *D. melanogaster* collected in the houses showed 1184 females and 50 males, and on 1400 *D. repleta*, 1388 females and 12 males.

The second test was designed to determine the distance and the extent to which flies from a given pit privy would enter houses and other privies. The privy chosen as a release point in the Latin section of Pharr, Texas, was particularly desirable because of its large *Drosophila* population and because it permitted relatively easy trapping for comparatively long distances in a sparsely settled area (Figure 1). To the west of the privy and extending northward there was a 6-foot tin fence which enclosed a large nursery. A vacant area extended for approximately 200 feet to the south. The release privy contained an estimated population of 10,000 flies composed of approximately 90 per cent *D. repleta* and 10 per cent *D. melanogaster*. Six traps, placed in the privy to obtain flies for marking, collected an estimated 2000 flies. At the same time four traps outside the Pharr, Texas, laboratory collected an additional 1000 flies which were approximately 90 per cent *D. melanogaster* and 10 per cent *D. repleta*.

All collected flies were transferred to a cylindrical cage 4 feet high and 2 feet in diameter, and were allowed to feed for 32 hours on a radioactive bait. At the end of the

[1] From the Communicable Disease Center, Public Health Service, U. S. Department of Health, Education and Welfare, Savannah, Georgia. Accepted for publication August 30, 1954.

[2] Maier, P. P., and Pimentel, D. (Unpublished Manuscript) "The Role of *Drosophila* as Filth Flies."

[3] Trade names are used as a means of identifying the products. Their use does not constitute endorsement by the U. S. Public Health Service.

Table 1.—Marked and unmarked *Drosophila* spp. trapped in houses following the exposure of baits treated with radioactive phosphorus in the pit privies on the respective premises, Edcouch, Texas, April, 1951.

	Trapping Period							
	First Night		Day			Second Night		
	Marked Flies			Marked *Drosophila*			Marked *Drosophila*	
House Number	Traps With	Traps Without	Total Collected	*repleta*	*melanogaster*	Total Collected	*repleta*	*melanogaster*
1	X		4	0	0	259	7	1
2	X		6	0	0	208	0	0
3		X	0	0	0	76	0	0
4	X		0	0	0	90	1	1
5	X		8	0	0	139	2	1
6	X		25	3	0	212	6	1
7	X		31	0	0	1158	21	4
8	X		7	0	0	162	0	3
9		X	1	0	0	8	0	0
10	X		37	5	3	700	8	1
Total	8	2	119	8	3	3012	45	12

feeding period about 98 per cent of the flies were well marked at levels from 2000 to 180,000 c.p.m. To release the flies the cage was placed over the privy seat and the flies shaken down into the pit during the late afternoon.

The recovery traps, similar to those used in the first test, were set north, northeast, east, and southeast from the release point (Figure 1). One trap was set in each privy pit and in each house on the premises chosen as check points. Traps were put out between 4 and 5 P.M. and collected between 8 and 9 A.M. With a few exceptions trapping continued for 4 nights on all premises. The results of trapping in the privy pit in which the marked flies were released would indicate that most of the *D melanogaster* had apparently left the privy immediately upon release (Table 2).

Based on the prerelease observations, this particular privy pit was more attractive to *D. repleta* than to *D. melanogaster*, which may have been a factor in the apparent tendency of *D. melanogaster* to leave the privy soon after release. Marked *D. repleta* in the release privy represented 15, 10, 16, and 7 per cent of the total trapped *D. repleta* on successive nights, indicating that a prerelease estimate of a 20 per cent marked population was essentially correct.

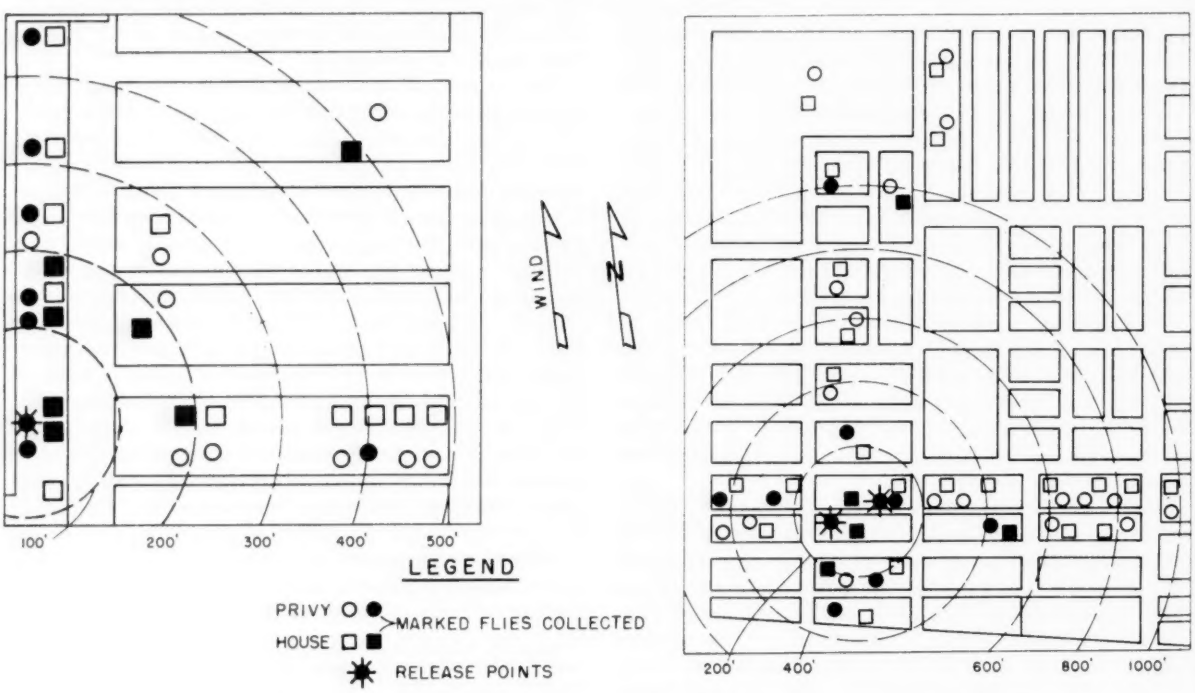


FIG. 1.—Sketch map showing *Drosophila* release points, collecting stations, and recovery points for migration test Number 2 (left) and test Number 3 (right), Pharr, Texas, May 1951.

Table 2.—The *Drosophila* groups trapped in the release privy, Pharr, Texas, May, 1951.

TRAP NIGHT	*D. repleta*		*D. melanogaster*	
	Total	Marked	Total	Marked
First	214	33	3	0
Second	1322	128	238	6
Third	850	132	26	0
Fourth	740	54	22	0
Total	3126	347	289	6

The results of trapping flies in the privies and houses away from the release point indicated that, in general, the majority of the flies collected in houses was *D. melanogaster* and in privies *D. repleta* (Table 3). The partial screening of some premises may have reduced catches of *D. repleta* since their larger size prevents most of them from passing through ordinary screening. Although a majority of privies contained primarily *D. repleta*, some privies contained mostly *D. melanogaster*, and a few, equal numbers of both species. Marked *D. repleta* and *D. melanogaster* were trapped as far as 500 feet northeast from the release point (Figure 1 and Table 3). A large proportion of the flies from privies apparently entered the houses. As high as 9.5 per cent of all *D. repleta* trapped in the houses within 50 feet of the release privy were marked. A comparison of the 9.5 per cent of *D. repleta* trapped in the houses to the estimated 20 per cent marked in the privy suggests that about 50 per cent of the flies in the houses had come from the privy used as a release point.

The third test was set up to replicate the second test and also to determine any differences in the migratory habits of *D. repleta* and *D. melanogaster*. Two privies 100 feet apart in the Latin section of Pharr, Texas, were selected as release points. One privy contained mostly *D. repleta* while the other contained chiefly *D. melanogaster*. The privies were advantageously located in a sparsely housed area where the traps could be set in all directions from the release points.

The privy with *D. repleta* was designated "R," and the privy with *D. melanogaster* as "M." Privy "R" had an estimated population of 10,000 *Drosophila* with 90 per cent *D. repleta*. Privy "M" had an estimated population of 5000 flies with 75 per cent *D. melanogaster*. To obtain flies for marking, six traps were placed in both privies for 5 days. Trapped flies were transferred each morning to holding cages made of 64-mesh-per-inch screen wire, 6 inches in diameter and 18 inches high. The flies from each privy were kept in separate cages.

The separation of the two species of *Drosophila* in each holding cage was accomplished by setting the holding cage on end, placing an empty holding cage on top of it, and inserting a piece of 18 by 14 mesh plastic screen between the two cages. The sleeves on the adjoining ends of the cages were opened and two lights placed near the top of the upper cage attracted the *Drosophila* upward. The meshes of the plastic screen insert allowed all *D. melanogaster* to pass through to the upper cage but only about 1 per cent of *D. repleta*. The few *D. repleta* that did enter the cage were easily removed with an aspirator. *D. melanogaster*, approximately 1000 in number, were placed in two holding cages, and about 3000 *D. repleta* were placed in four cages.

Flies in each cage were fed for 32 hours on banana bait treated with P^{32}, then the *D. melanogaster* were released in privy "M" and *D. repleta* in privy "R." The trapping methods were similar to the previous test, with the exception that the check points were approximately 75 feet from one another. Traps were set in all directions from the release points (Figure 1).

Trapping for released *D. repleta* in privy "R" on the first and second days resulted in 10 and 17 per cent recoveries (Table 4). This was lower than the 30 per cent estimated as marked. There was a further decrease in the numbers of marked flies on the third and fourth days. In privy "M," about 36 per cent marked *D. melanogaster* were trapped the first day (Table 4). This was about 8 per cent higher than the 28 per cent estimated marked. On the second and third days there was a sharp decrease in the number of marked *D. melanogaster* trapped, and on the fourth day none were trapped. These results agree favorably with the second test, and indicate that the additional 900 *D. melanogaster* in the release privy of the second test probably did not influence greatly the dispersal activities of the privy population. Tables 5 and 6 summarize the results of collections made in the third test from houses and privies within 2000 feet of privies "R" and "M." *Drosophila repleta* were captured in both

Table 3.—Results of trapping *Drosophila* spp. groups for 4 days in houses and privies away from release point, Pharr, Texas, May, 1951.

FEET FROM RELEASE POINT	TRAPS PLACED IN HOUSES				TRAPS PLACED IN PRIVIES			
	Total Number Flies Collected		Number Marked Flies		Total Number Flies Collected		Number Marked Flies	
	repleta	*melanogaster*	*repleta*	*melanogaster*	*repleta*	*melanogaster*	*repleta*	*melanogaster*
50 or less	105	158	10	2	1870	276	20	5
51–100	109	31	2	1	—	—	—	—
101–200	47	195	0	4	2766	736	6	1
201–300	35	703	0	0	436	359	2	1
301–400	13	44	0	0	1014	1259	1	7
401–500	366	403	1	0	736	819	0	3
501–800	7	59	0	0	1603	1526	0	0
Total	682	1593	13	7	8425	4975	29	17

Table 4.—Marked and unmarked *Drosophila* spp. groups collected in traps at the privies where *D. repleta* and *D. melanogaster* were released, May, 1951.

Day Trapped	Privy "R"				Privy "M"			
	Total Collected		Total Marked Flies		Total Collected		Total Marked Flies	
	repleta	*melanogaster*	*repleta*	*melanogaster*	*repleta*	*melanogaster*	*repleta*	*melanogaster*
First	83	0	8	0	12	60	0	22
Second	72	24	12	0	18	73	0	1
Third	98	1	5	0	0	66	0	2
Fourth	66	4	2	0	58	24	2	0
Total	319	29	27	0	88	223	2	25

houses and privies up to 1000 feet from the release point, whereas *D. melanogaster* were not collected farther than 500 feet from the release point. Many more *Drosophila* were collected from the privy pits than from the houses.

In the last two tests, more *D. melanogaster* than *D. repleta* were trapped in most of the houses (Tables 3 and 5). This is probably because the majority of the houses were partially screened, the screens acting as a greater barrier to *D. repleta* than to *D. melanogaster*. In privies the *Drosophila* population was mostly *D. repleta*, and the total numbers found were much greater than in houses.

In all three tests, marked flies left the pits of the privies soon after they were released, indicating that the two major species of *Drosophila* in the test area disperse rather rapidly from the pit privies in which they are found. Both species were recaptured in privies and houses in significant numbers. It appears likely that most *Drosophila* entering houses in this area have at one time or another frequented privies.

SUMMARY.—Three tests were carried out at Edcouch and Pharr, Texas, in 1951 to determine the extent to which *Drosophila* migrated from privy pits into houses, using flies marked with radioactive phosphorus. In the first test, treated baits were placed in the pits of 10 privies and marked flies were subsequently recovered in 8 of the 10 adjacent houses. In the second test, flies were trapped, marked, and released in a privy pit; during the following 4 nights marked specimens were recovered in houses and privy pits as far as 500 feet from the release point. In the third test approximately 1000 marked *D. melanogaster* were released in one privy pit and 3000 marked *D. repleta* were released in another privy pit 100 feet away. Subsequent trapping indicated that both species dispersed rapidly from the release privies to other privies and houses in the nearby area. *Drosophila melanogaster* were recaptured as far as 500 feet from the release point and *D. repleta* almost 1000 feet from the release point. The three tests demonstrated there was extensive migration of *Drosophila* from privy pits to houses in the area studied. The indications were that a major portion of the *Drosophila* which were found in the houses had at one time or another frequented privies.

Table 5.—*Drosophila* spp. groups trapped in houses away from the release points during a 4-day period following release, Pharr, Texas, May, 1951.

Feet from Release Points "R" and "M"	*Drosophila repleta*		*Drosophila melanogaster*	
	Total	Marked	Total	Marked
30– 110	39	2	29	1
111– 250	41	1	118	0
251– 370	5	0	37	0
371– 530	35	0	40	1
531– 710	8	0	19	0
711– 820	0	0	1	0
821–1100	343	1	106	0
1101–1500	200	0	121	0
1501–2000	2	0	24	0
Total	673	4	495	2

Table 6.—*Drosophila* spp. groups trapped in privies away from the release points during a 4-day period following release, Pharr, Texas, May, 1951.

Feet from Release Points "R" and "M"	*Drosophila repleta*		*Drosophila melanogaster*	
	Total	Marked	Total	Marked
90– 240	625	15	67	3
241– 500	2434	3	250	3
501– 670	771	0	221	0
671– 910	268	0	39	0
911–1000	1852	1	76	0
1001–1250	879	0	105	0
1251–1380	1497	0	64	0
1381–1590	408	0	154	0
1591–2000	80	0	28	0
Total	8615	19	1004	6

Apple Mite Populations Under Six Control Programs[1]

G. Edw. Marshall, *Purdue University Agricultural Experiment Station, Lafayette, Indiana*

The control of the mites, *Tetranychus bimaculatus* Harvey and *Metatetranychus ulmi* (Koch), offered greater difficulty in 1953 than any other pests of apples in Indiana. The severe drought may have been especially favorable to rapid mite population increases. There was no rain between July 27 (1.81 inches at that time) and harvest. By June 25 they had bronzed the foliage on some trees and they were still doing considerable damage at the time of Winesap harvest; a challenge to those studying methods of control to find some more economical material or method of holding them in check than is now available. Furthermore, the performance of mites in 1953 offers little hope that they have reached the limit of their population potential. There may have been methods and materials which would have prevented mites from building up to damaging numbers at any time during the season as is indicated by Lienk & Chapman (1953) through their work in the control of newly hatched larvae and eggs during the period between the delayed dormant and the 10-day spray. It also seems reasonable to state that in 1953 there was no satisfactory control within the economic limits of our growers in this section of the Ohio Valley. Pierce (1953), working with two or three species of mites of pecans concluded that one to two sprays per season would preclude damage by them. Our experience with the two or three species of mites that attack apple lead to the belief that mites of apples will become more difficult to control as will most similar species attacking other crops and against which spraying control is a regular practice.

The 1953 studies were made at the Fruit Insects Research Farm in Southern Indiana on three varieties, Jonathan, Turley and Delicious. Prior to the mite control studies, the entire orchard was given a treatment of sulphur and DDT for control of apple scab and insects. Each treatment was repeated at least three times on each variety on isolated single tree plots. A conventional type sprayer was used and a pressure of approximately 600 pounds was maintained, the aperture being $\frac{8}{64}$ inch. These sprays were applied from the ground as thoroughly as possible each time, and in keeping with necessary safety measures. The trees were approximately 25 feet in height and had been pruned the preceding winter. Approximately 12.5 gallons per tree were used and certainly, any materials which would not control in a satisfactory manner as they were used in this study, would not be practicable in commercial orchards.

Mite counts were taken by the same person each time and on the dates given in table 1. An attempt was made to make counts every 4 days. Though many other time intervals between counts have been used in the past, this one provides the most comprehensive record of mite activity at all times. Herein lies much of the value of this study because mite counts taken at 4 day intervals over a period of more than 6 weeks revealed slight differences in varietal preference of mites and how difficult they are to control over the entire season. In making counts five mature full sized leaves were selected at random around the inside of the tree near the trunk and at the base of the scaffold branches and five around the outside at a height of approximately 5 feet above the ground. The latter five were mature leaves selected at random around the tree so as to avoid those of terminal branches. Rather, they were selected from among those 6 inches to 1 foot inside the canopy of leaves. Mobile forms of mites on each leaf were counted immediately, using a hand lens and the data were recorded as mites per 10 leaves.

By making counts every 4 days, it was found that in certain instances, one variety needed a spray application at a shorter interval than another and such treatments were so-applied, to prevent permanent foliage and subsequent fruit injury by mites. This led to a variety-wise spray program for the season. The number of sprays that were needed in each case are shown in table 1. The counts given in the last column indicate how effectively the materials controlled the mites at harvest time on each variety. The treatment in this instance was parathion, and as Newcomer & Dean (1953) found, mites soon become resistant to it. A review of the literature of recent mite control studies was made and it was found that Haynes *et al.* (1953) used butoxypolypropylene glycol alone and the same with a wetting agent. Results reported appear to be similar to those reported here. Likewise, Rodriguez & Waltman (1953) presented 1953 data to members of the Midwest Fruit Insect and Disease Control Conference which showed some interesting results using six different materials in two applications. Counts were taken at intermittent intervals. In their studies the mite counts were not taken at short intervals over a period long enough to give the type of picture presented in table 1.

Cochran (1953) studying six materials, DDT-parathion combination, R-242, and 2-peptadecyl glyoxalidine acetate 34 per cent and including treatments, 3, 5, 6 as shown in table 1, found that good control was obtained with all by adding the acaracides to the calyx and all cover sprays. Though counts were taken over a period of $4\frac{1}{2}$ months, an interval of 1 week was left between counts which was almost one generation of mites in length. Gould (1953) applied a single spray of eight different materials all of which were mentioned above except schradan 90 per cent and Systox, and his mite population counts taken 2, 8, 14, 18, 20, and 27 days after the application show that none of the materials prevented serious damage to the foliage. Work by Hintz (1953) clarified at least one of the reasons why one or a few sprays do not control mite populations. Using 11 formulations in a laboratory study of the control of European red mite winter and summer eggs, he found that normal concentrations would not be practicable under commerical conditions in the orchard. Huffaker & Kennett (1953), in a study of the cyclamen mite on strawberries found that either hand or chemical removal of predators results in a

[1] Journal Paper No. 789 of the Department of Entomology. Accepted for publication Aug. 30, 1954.

Table 1.—Comparison of Acaricides and number of applications required to control mites on three varieties[a] of apples.

Treatment Date		Materials and Amount Applied per 100 Gallons																
		1 Pt.[b]			¾ Lb.[c]			1½ Lbs.[d]			2½ Lbs[e]			1½ Lbs.[f]			2 Lbs.[g]	
		J	D	T	J	D	T	J	D	T	J	D	T	J	D	T	J	D
June	25	18[h]	53	43	11	38	14	3	28	29	6	35	14	3	48	45	3	6
June	26	X[i]	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
June	30	18	84	4	0	0	0	3	0	3	1	0	0	0	9	13	0	3
July	3	5	84	112	0	9	0	17	1	0	0	0	17	5	0	5	1	0
July	3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
July	7	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	31
July	8																X	X
July	11	0	0	120	0	0	0	0	0	0	0	7	0	0	13	0	0	10
July	13			X								X			X			X
July	18	10	61	13	0	0	0	2	0	0	0	1	5	0	1	0	0	32
July	20	X	X	X								X	X					X
July	21				0	0	0	0	0	0	0			30	0	11	0	
July	21													X		X		
July	22	0	0	0	2	2	0	0	0	0	0	0	0	5	0	1	1	61
July	27	4	175	0	30	7	0	4	0	0	0	4	6	0	14	36	0	40
July	28	X	X		X	X		X				X	X		X	X		X
August	1	4	6	2	2	2	2	0	0	1	0	0	0	0	2	0	0	57
August	4	X	X	X	X	X	X											X
August	5	0	0	0	55	0	0	0	0	0	4	0	0	3	0	1	0	151
August	10	1	0	0	105	2	0	0	1	0	0	3	0	18	28	0	9	108
August	11				X	X								X	X			X
August	18	1	0	16	4	1	0	0	13	3	1	2	0	0	1	1	36	227
August	19	X		X	X	X		X	X								X	X
August	25	0	1	0	28	1	6	0	0	0	2	71	0	3	45	26	340	357
August	26				X	X	X				X	X	X	X	X	X	X	X
September	8	0	1	0	40	43	130	0	1	0	28	4	93	5	51	8	376	510
No. sprays needed		6	5	6	7	7	4	3	3	3	3	6	5	5	6	5	5	10

[a] J—Jonathan, D—Delicious, T—Turley.
[b] Di (*p*-chlorophenyl) methyl carbinol.
[c] Ethyl *p*-nitrophenyl thionobenzenephosphonate.
[d] 2-(*p*-tert-butyphenoxy) isopropyl 2-chloroethyl sulfite.
[e] N, N-diethyl thiocarbonyl-o, o-diisopropyl dithiophosphate.
[f] 4, 4'-dichlorobenzilic acid ethyl ester.
[g] o, o-diethyl-o-nitrophenyl thiophosphate.
[h] All figures represent the number of mites on ten leaves.
[i] X means that the plot was sprayed on that day.

mite increase. Although the mite studied is not one of those attacking apple, there is an application to be made with respect to using acaracides on apples which kill the injurious mites perhaps, but just as certainly the parasites and predators.

Based on Indiana studies reported in table 1, it would seem that 2(*p*-tert-butyphenoxy)-1-isopropyl-2-chloroethyl sulfite was the most dependable material used. *p*-Chlorophenyl *p*-chlorobenzenesulphonate has shown similar effectiveness (Lienk & Chapman 1953). There was no noticeable injury to the fruit or foliage from any of the acaracides used. Extreme drought, failure of the material to control mites (in some cases) and the excessive number of sprays applied all caused premature foliage drop in certain instances.

References Cited

Cochran, Boyd. 1953. Results of experiments on the control of orchard mites. Proc. 29th Annual Meeting of the Cumberland-Shenandoah Fruit Workers Conf.: 38–40.

Gould, Edwin. 1953. Report of mite sprays for European red mite. Proc. 29th Annual Meeting of the Cumberland-Shenandoah Fruit Workers Conf.: 71–80.

Haynes, Harry L., Philip Granett, Bertram Sacktor, and Thomas G. Bowery. 1953. A butoxypolypropylene to control the European red mite on apples. Jour. Econ. Ent. **46**(6): 1020–5.

Hintz, Howard W. 1953. Laboratory tests of acaracides on eggs on European red mite. Jour. Econ. Ent. **46**(1): 112–5.

Huffaker, C. B., and C. E. Kennett. 1953. Biological control of cyclamen mite. Jour. Econ. Ent. **46**(5): 802–12.

Lienk, S. E., and P. J. Chapman. 1953. Evaluation of acaracides on orchard mites in 1952. Jour. Econ. Ent. **46**(6): 1085.

Newcomer, E. J., and E. P. Dean. 1953. Control of orchard mites resistant to parathion. Jour. Econ. Ent. **46**(5): 894.

Pierce, W. C. 1953. Studies of mites and their control on pecan in Louisiana. Jour. Econ. Ent. **46**(4): 561–5.

Rodriguez, J. G., and C. S. Waltman. 1953. Results of Acaracide Tests. A Memo. of the Kentucky Agricultural Experiment Station.

Some Factors Influencing the Effectiveness of Piperonyl Butoxide-Pyrethrins Combinations for the Control of Insects in Stored Grains[1]

H. O. SCHROEDER,[2] *Research Laboratories, Fairfield Chemical Division, Food Machinery and Chemical Corporation, Baltimore, Maryland*

The protection of food and feed grains from the ravages of insects is a matter of increasing importance throughout the world. The magnitude of these losses depends on many factors among which are temperature, kind and quality of grain, moisture content of stored grain, as well as the species and vigor of insects involved. These factors also have a direct bearing on the efficiency of whatever measures are undertaken to prevent infestation of grain or to control established infestations.

Powders[3] containing piperonyl butoxide and pyrethrins in a suitable diluent are available for direct application to grain to prevent infestations from becoming established. Sarles & Vandegrift (1952) have shown the remarkably non-toxic nature of these ingredients to warm blooded animals. Application of the powders at the recommended rates therefore can be made directly to the whole grain regardless of the end-use to which it is to be put.

It was the purpose of this study to show how some factors such as moisture content of grain, age of insects and age of treatments might influence the performance of the protectant dusts. It should be understood that these laboratory tests were conducted under ideal conditions for insect survival and reproduction. Introduced populations in test samples were generally more than 100 times that of infested grain which normally would be graded "weevily." The results therefore indicate trends which might be useful in interpreting field data and in suggesting changes in general recommendations to suit unusual situations.

A low moisture content in grain tends to reduce insect activity (Cotton 1947) and usually results in lower dosage requirements of insecticides or fumigants used in their control. Conversely, at a higher moisture content, insect activity increases and higher dosages of toxicants are required. Wilbur (1952) has shown that in wheat treated with a powder containing piperonyl butoxide and pyrethrins the survival of rice weevils and the rate of reproduction increases when the moisture content of the grain is high. Similar tests on corn and the effect of certain other factors are discussed in the present paper.

Table 1.—Effect of grain moisture on control of rice weevils exposed to protectant treatments on corn.[a]

Concentration (Per Cent)			Dosage: (Pounds/1000 Bushels)				
Piperonyl Butoxide	Pyrethrins	Moisture in Grain	35	50	70	100	140
	Seven-Day Exposure			*Mortality—(Per cent)*			
0.8	0.05	10	—	74	91	98	—
.8	.05	12	—	60	80	95	—
.8	.05	13	—	45	67	92	—
.8	.05	14	—	37	58	81	—
.8	.05	15	—	—	58	81	93
1.6	0.1	15	36	69	96	—	—
Untreated control: Mortality = 0							
	Thirty-Day Exposure			*Mortality—(Per cent)*			
0.8	0.05	10	—	82	99	100	—
.8	.05	12	—	74	86	100	—
.8	.05	13	—	53	88	100	—
.8	.05	14	—	54	80	99	—
.8	.05	15	—	—	79	97	100
1.6	0.1	15	71	98	100	—	—
	Sixty-Day Exposure			*Increase in Population—(Per cent)*			
0.8	0.05	10	—	24	1	0	—
.8	.05	12	—	65	27	1	—
.8	.05	13	—	108	30	3	—
.8	.05	14	—	169	64	6	—
.8	.05	15	—	—	108	12	4
1.6	0.1	15	120	6	0	—	—
Untreated control: 12% moisture			211% Population increase				

[a] Average of three replications. Total of 300 insects per treatment.

Methods and Materials.—The tests were made in the laboratory in a room held at a constant temperature of 80° F. and 60 to 70 per cent relative humidity. The moisture content of the grain was 12 to 13 per cent except as noted otherwise. All tests were made by a jar method by which 200 grams of grain was placed in pint mason jars. The desired dosage of protectant powder was then added and thoroughly mixed with the grain. The test insects were introduced and the jars closed with 40-mesh brass strainer cloth fitted into the screw top. The rice weevil, *Sitophilus oryza* (L.), was used as the principal test insect. Four other common grain infesting species were included in the experiment in which species differences were determined. The insects were screened out of the test samples of grain and examined after 7, 30, and in some cases, 60 days.

Results.—*Effect of Moisture.*—Shelled yellow corn was dried to a moisture content of 9 per cent. Water was added to obtain test lots of corn containing 10, 12, 13, 14 and 15 per cent of moisture. This grain was treated with various dosages of Pyrenone Grain Protectant. At rates greater than 100 pounds per 1000 bushels all of the powder may not adhere uniformly to the grain. To insure an even dispersion at a higher dosage level, a protectant at double the usual concentration applied at lower rates was also used to treat corn containing 15 per cent of moisture.

The results of three replications of this experiment are shown in table 1. It is to be noted that at the recommended dosage rate of 100 pounds per 1000 bushels, good mortality was obtained at 10, 12 and 13 per cent moisture. A high mortality also was obtained at the 15 per cent moisture level when the dose was increased 40 per cent. A mortality of 99 and 97 per cent of weevils was obtained with a 100 pound treatment after 30 days of exposure at the high moisture levels of 14 and 15 per cent, respectively. On grain of 15 per cent moisture the dosage of active ingredients was increased 40 per cent by using the regular protectant at 140 pounds and the more highly concentrated powder at 70 pounds per 1000 bushels. This

[1] Accepted for publication September 8, 1954.

[2] The author acknowledges the able assistance of Owen F. Greenwell, Jr., who contributed immeasurably in both the care of the insect cultures and the conduct of the experiments.

[3] Certain combinations of piperonyl butoxide and pyrethrins are marketed under the trade names of Pyrenone Grain Protectant and Prenone Wheat Protectant. The former contains 0.8% technical piperonyl butoxide and 0.05% pyrethrins; the latter contains 1.1% technical piperonyl butoxide and 0.08% pyrethrins.

Table 2.—Effect of age of treatment on control of rice weevils in corn and wheat.[a]

Age of Treatment	Per Cent Mortality After (Days): 7	30	60	Adults Emerging at 60 Days
T-414A[b] Tests on Corn				
30 Days	98	99	100	0
Fresh	99	99	100	0
Untreated	1	3	2	305
60 Days	92	96	95	4
Fresh	99	100	100	0
Untreated	1	2	3	256
90 Days	85	89	87	12
Fresh	98	100	100	0
Untreated	1	4	7	191
T-460[c] Tests on Wheat				
30 Days	68	84	28	373
Fresh	97	99	69	68
Untreated	0.2	1	1	2306
60 Days	42	51	18	1062
Fresh	95	99	76	56
Untreated	1	5	1	1229
90 Days	30	46	16	582
Fresh	98	100	89	41
Untreated	0.2	2	1	1483

[a] Average of five paired replicates. Total of 500 insects per treatment.
[b] Contains 0.8% piperonyl butoxide and 0.05% pyrethrins; used at 100 lbs. per 1000 bu.
[c] Contains 1.1% piperonyl butoxide and 0.08% pyrethrins; used at 75 lbs. per 1000 bu.

increase in dosage resulted in high mortalities of rice weevils after 7 days and in complete kills after 30 days of exposure. Under the conditions of these laboratory tests a reduction in mortality occurred at the customary 100 pound dosage rate when the moisture content of the grain was more than 13 per cent. These results agree with those obtained by Wilbur in tests on wheat.

Counts made after 7 and 30 days of exposure give a good measure of effectiveness of the treatment against insects introduced into the treated grain. After 60 days any oviposition by the introduced weevils will have resulted in the emergence of a new generation.

Table 3.—Effect of age of protectant treatments on mortality of rice weevils emerging in treated grain as a result of egg deposition prior to treatment.

Treatment	Age of Treatment (Days)	Mortality (Per Cent)
	Tests on Corn	
T-414A[a]	42	9
	35	12
	28	15
	21	20
	14	32
	Tests on Wheat	
T-460[a]	42	3
	35	17
	28	10
	21	13
	14	24

[a] See table 2.

Table 4.—Effect of age of rice weevils on susceptibility to protectant treatments on corn.[a]

Concentration	Age of Weevils (Weeks)	No. Jars[b]	Per Cent Mortality after (Days): 7	30	60	Reproduction (Per Cent): Increase	Reduction from Normal[c]
0.8% piperonyl butoxide 0.05% pyrethrins	1	3	66	88	73	23	93
	2	8	78	92	76	18	95
	3	8	79	92	78	36	90
	4	8	87	98	86	36	90
	5	7	92	99	84	46	87
Untreated		4	0	0	2	346	0

[a] Dosage: 50 pounds per 1000 bu. Results represent average of mortalities from two cultures.
[b] Fifty rice weevils per jar.
[c] Per cent reduction in reproduction $= \frac{R - R^1}{R} \times 100$.
R = Per cent increase of reproduction in untreated.
R^1 = Per cent increase of reproduction in treated.

The data on reproduction show that the increase in population is very low unless the moisture in the grain exceeds 13 per cent. Reproduction was kept under control even in grain of 15 per cent moisture at a dosage rate of 140 pounds for the regular protectant or 70 pounds per 1000 bushels when the concentration of active ingredients was doubled.

Effect of Age of Treatments.—Tests in this laboratory have shown that protectant powders have an excellent shelf-life. When the material was applied to grain its effective life decreased. Tests were set up to determine under laboratory conditions the period of residual effectiveness of these powders when applied to grain. Grain was treated, stored in pint mason jars and at monthly intervals it was infested and the effect on rice weevils compared to that of similar fresh treatments. The results, table 2, obtained from these tests showed that treatments on corn remained highly effective for 90 days. Treatments on corn also remained effective for a longer period than similar treatments on wheat. It should be pointed out that the laboratory conditions were ideal for insect activity and reproduction. Similar conditions seldom prevail under circumstances of practical use. These results therefore give no direct indication of the effective period of protection in the field, where it has been shown to be much longer than that obtained under laboratory conditions.

Table 5.—Comparative susceptibility of five species of grain insects to protectant treatments applied to wheat.[a]

Species	Check	Dosage per 1000 Bushels: 15	20	25	35	50
		Per cent Mortality After 7 Days				
Flat grain beetle[b]	2	71	—	89	97	—
Saw-toothed grain beetle[c]	0	—	70	—	79	90
Lesser grain borer[d]	0	—	39	—	53	52
Rice weevil[e]	0	—	10	—	34	54
Cadelle larvae[f]	0	—	1	—	0	2
		Per cent Mortality After 30 Days				
Flat grain beetle	40	96	—	95	100	—
Saw-toothed grain beetle	0	—	78	—	89	99
Lesser grain borer	0	—	64	—	88	99
Rice weevil	0	—	18	—	43	60
Cadelle larvae	10	—	5	—	40	30

[a] Average of two tests. Total of 100 insects per treatment.
[b] *Laemophloeus pusillus* (Schönh.)
[c] *Oryzaephilus surinamensis* (L.)
[d] *Rhyzopertha dominica* (F.)
[e] *Sitophilus oryza* (L.)
[f] *Tenebroides mauritanicus* (L.)

In the laboratory tests, some of the loss of effectiveness of treatments on wheat occurred within the time required for weevil eggs and immature forms to complete development and emerge from the kernels as adults. This developmental period of weevils ranges from 4 to 6 weeks or more depending on temperature. They obviously would not be exposed to the treatment prior to emergence. To obtain more information along this line, test lots of wheat and shelled corn were subjected to oviposition of rice weevils for a period of 10 days. The adults were then removed, the grain divided and held in test jars. At weekly intervals, thereafter, the grain in two of these jars was treated with protectant powder. No weevils were present when the last treatment was made but emergence probably started shortly afterwards. The entire series was examined on the 49th day after the end of the oviposition period. Thus there was a period of 12 days during which weevils were emerging into the treated grain and during that time the treatments were not disturbed. Obviously the exposure period could have varied from 12 to less than 1 day, but this variation should have been essentially the same for all treatments. The resulting data are given in table 3 and show that weevils developing from eggs deposited shortly before the grain was treated had a better chance of survival than those developing from eggs deposited several weeks prior to treatment.

Effect of Age of Rice Weevils.—Adult rice weevils were permitted to deposit eggs for 7 days in shelled corn after which they were removed. When adults of the new generation began to appear they were removed from the grain at weekly intervals until no more emerged. The various age groups were then exposed to treated grain in jar tests in the usual manner. The results of two replications are summarized in table 4, and show mortalities at 7, 30 and 60 days as well as the per cent increase in population after 60 days.

At the fractional dosage rate of 50 pounds per 1000 bushels 92 per cent of the weevils 5 weeks old were dead compared to only 66 percent of the weevils 1 week old. This shows that young weevils were more resistant to the treatment used than older weevils. There was no appreciable difference in the rate of reproduction between the different age groups, and populations were reduced from 87 to 95 per cent of that obtained in untreated grain.

Comparative Susceptibility of Different Insect Species.—As would be expected there was a marked species difference in the susceptibility of insects to protectant treatments. Five species of insects, commonly found in stored grain, were exposed to wheat treated with Pyrenone Wheat Protectant in the usual manner. The species used, the dosage rates of the treatments and the resulting mortalities after 7 and 30 days are shown in table 5. The flat grain beetle, the saw-toothed grain beetle and the lesser grain borer were much more susceptible than the rice weevil. Cadelle larvae were affected more slowly but appeared to be about as susceptible as rice weevils.

SUMMARY AND CONCLUSIONS.—The development of insects in stored grain is affected by many factors, some of which have a direct bearing on the effectiveness of insect control methods. Tests were made in the laboratory to determine the influence of some of these factors on the efficiency of protectant dusts containing pyrethrins and the pyrethrum synergist, piperonyl butoxide, in a suitable carrier. Tests were made in pint mason jars on corn and wheat using the rice weevil as the principal test insect.

Results obtained showed that as the moisture content of grain was increased the survival and reproduction of weevils also increased. When the moisture content rose above 13 per cent the possibility of complete control at conventional dosages was reduced; however, a 40 per cent increase in the usual dose gave excellent control of rice weevils even at 15 per cent moisture.

Protectant treatments on corn showed very little loss of effectiveness against rice weevils for 3 months after application in spite of population pressure and the optimum conditions for growth provided in the laboratory. Protectants applied to wheat had a somewhat shorter residual period of effectiveness.

Young rice weevils were less susceptible to the treatments than older weevils. Similarly, weevils emerging in treated grain were less susceptible to the treatment than an introduced population.

There was a wide difference among species in susceptibility to the treatments as made in these tests. According to decreasing susceptibility, the species fell into the following order: flat grain beetle, saw-toothed grain beetle, lesser grain borer, rice weevil and the larva of the cadelle.

REFERENCES CITED

Cotton, R. T. 1947. Insect pests of stored grain and grain products. Burgess Publishing Co., Minneapolis, Minn. 242 pp.

Sarles, M. P., and W. B. Vandegrift. 1952. Chronic and oral toxicity and related studies on animals with the insecticide and pyrethrum synergist, piperonyl butoxide. Amer. Jour. Trop. Med. and Hyg. 1(5): 852–83.

Wilbur, D. A. 1952. Effect of the moisture content of wheat on the toxicity of insecticidal dusts containing piperonyl butoxide and pyrethrins. Jour. Kan. Ent. Soc. 25(4): 121–5.

Relationship of Ants to Fly Control in Puerto Rico[1]

DAVID PIMENTEL

The general level of fly incidence in cities and towns of Puerto Rico appears to be below that observed in many sections of continental United States. Although the vast majority of homes in Puerto Rico are without window screens, surprisingly few more flies are found in these unscreened houses than in screened houses in continental United States. This condition exists when actually there is abundant breeding material present, and temperatures are favorable for fly breeding throughout the year. Laboratory and field observations of ants attacking various stages of flies suggested that ants might be an important factor in suppressing the fly population in the cities and towns of Puerto Rico. In Hawaii the black ant, *Pheidole megacephala*, was reported by Phillips (1934) to keep the house fly population "down to negligible numbers."

PRELIMINARY OBSERVATIONS.—The fire ant, *Solenopsis geminata* (F.), was observed to enter a laboratory in San Juan, Puerto Rico, and kill all the newly emerged adults in a culture of house flies *Musca domestica* L. The ants attacked and killed the flies as they emerged from the puparia. Not one fly survived the vicious attack.

Fire ants were seen attacking and killing full-grown larvae of *M. domestica*, *Phaenicia* spp., *Callitroga macellaria* (F.), and *Sarcophaga* spp. near garbage cans. Few larvae were able to escape these ants and pupate. In a number of instances pupae of the house fly and *Phaenicia* spp. were carried to the ants' nest. Fire ants were also observed attacking and killing adult flies as they emerged from the puparia. In observations of a number of garbage cans in the San Juan area, fire ant nests were found to be especially numerous near these cans. In most instances ants were entering and leaving the cans in a steady stream. At one can, where *C. macellaria* larvae covered the top of the garbage in a squirming mass, the fire ants' nest was found to be a network of tunnels extending from beneath the can outward for a radius of $2\frac{1}{2}$ feet.

CAGE TESTS.—In view of these observations a study was made to determine more accurately the possible effects ants might have upon a given fly population. Two large partially screened cages (4′ wide, 8′ long, and 7′ high) were set up on a rectangular grassy area 20′ by 30′ surrounded by concrete. One of these cages was protected by a barrier to prevent ants from getting inside, while ants were allowed free acess to the other cage.

Two larval rearing containers each containing 1,000 house fly eggs were placed in each cage. The larval medium was kept very moist, simulating conditions found in garbage cans. This tended to force the larvae to leave the containers to pupate, as usually happens in the field. At the end of 7 days the rearing containers were removed and replaced with others containing 1,000 eggs each. These fly breeding conditions were considered to approximate relatively heavy fly breeding conditions in a garbage can.

Two hours after the containers were placed in the unprotected cage small ants, *Solenopsis corticalis* Forel,[2] were observed carrying away fly eggs. Later, individuals of a larger species, *Tapinoma melanocephalum* (F.), were seen carrying eggs and newly hatched larvae to their nest. These two species of ants did not dispose of more than 2 per cent of the fly eggs and first stage larvae, due to the fact that the eggs hatched rapidly and the young larvae moved down into the larval medium where the ants could not reach them.

During the early part of the fourth day full-grown larvae began to leave the containers to pupate. Shortly after the first larvae dropped to the ground, fire ants attacked in force. A few of the larvae which were killed were carried away to the main nest located about 4 feet from the cage. Then to ease their struggle with the heavy larvae, these ants began to build small auxiliary storage nests near and under the larval containers. The ants then tunneled most of the way to the food supply. In a few instances fire ants were observed to crawl over the top of the wet larval media and attack larvae which came to the surface to pupate.

During the peak of pupation, which occurred at night, the ants killed the larvae but did not carry many of them away. The ants resumed the removal of the dead larvae as soon as daylight came and fewer larvae were pupating. During the peak of pupation some of the larvae were able to escape and pupate. From 50 to 70 per cent of the larval population were killed by the fire ants.

The crazy ant, *Paratrechina longicornis* (Latr.), was also present in the unprotected cage. Individuals of this species carried off a few larvae which crawled outside the working area of the fire ants. No more than 0.5 per cent of the larval population were killed by crazy ants. *Pheidole subarmata borinquensis* Whlr.[2] workers and soldiers were seen killing full-grown house fly larvae, but they killed less than 0.1 per cent.

After all the surviving larvae had pupated and a few pupae were left scattered on the surface of the ground, the fire ants struggled with the pupae and dragged some of them into their nests. They did not remove many, however, because the large pupae were difficult to handle. Although the fire ants could not cut through the puparia and get at the pupae, they did attack the adult flies as they emerged in the nest.

The only ant able to kill *Musca domestica* in the pupal stage was the smallest ant, *Solenopsis corticalis*. These ants bored a hole about 0.5 mm. in diameter in the walls of puparia, then entered and consumed the pupae inside. They did not choose any particular spot on the puparium to make the entrance hole, but did select pupae with thinner walled puparia. However, they did not kill more than 0.1 per cent of the pupae.

Fire ants killed 20 to 30 per cent of the flies as they emerged from the puparia. Frequently, the flies which escaped the fire ants were caught by the fast-moving crazy ants. Crazy ants captured and killed from 5 to 10 per cent of the emerging adult flies.

The reduction of the fly population in the cage not pro-

[1] Contribution from the Communicable Disease Center, Public Health Service, U. S. Department of Health, Education, and Welfare, San Juan, Puerto Rico. Accepted for publication September 9, 1954.

[2] Identified by Dr. M. R. Smith, Entomology Research Branch, Agr. Res. Serv., U.S.D.A.

Table 1.—House flies which survived from 2,000 eggs per test in cages protected and unprotected from ants.

Test Number	Survival in Cage			
	Protected from Ants		Unprotected from Ants	
	Number	Per Cent	Number	Per Cent
1	1,800	90	127	6
2	1,600	80	108	5
3	1,700	85	342	17[a]
4	1,800	90	423	21[a]
5	1,800	90	184	9
6	1,600	80	94	5
7	1,800	90	89	4
8	1,800	90	93	5
9	1,800	90	79	4
10	1,700	85	160	8
Total or Average	17,400	87	1,699	8[b]

[a] Rain occurred most of the night during heaviest pupation. See Influence of Weather.
[b] Percentage reduction: 91.

Table 2.—House flies which survived from 10,000 eggs per test in cages protected and unprotected from ants.

Test Number	Survival in Cage			
	Protected from Ants		Unprotected from Ants	
	Number	Per Cent	Number	Per Cent
1	8,800	88	2,300	23
2	9,000	90	2,600	26
3	8,400	84	2,700	27
4	8,400	84	1,800	18
5	8,800	88	2,100	21
6	8,600	86	3,000	30
Total or Average	52,000	87	14,500	24[a]

[a] Percentage reduction, 72.

tected from ants was highly significant (Table 1). The ants were responsible for killing an average of 91 per cent of the potential fly population between the egg and adult stages in the unprotected cage (Abbot 1925). The results obtained under the stated conditions indicated that ants are probably one of the more important factors in suppressing fly populations in municipalities of Puerto Rico.

To find how effective the ants would be under extremely heavy house fly breeding conditions, 10,000 house fly eggs were placed in ample larval media in each of the test cages. Again the reduction of the fly population in the unprotected cage was highly significant (Table 2). The ants were responsible for killing an average of 72 per cent of the potential fly population between egg and adult stages in the unprotected cage in these tests. It will be noted that the ants were significantly less effective in the 10,000-egg tests than in the 2,000 egg tests (Tables 1 and 2). This may account for the larger fly populations which are found at dumps, dairy farms, poultry farms, and sugar processing plants, where fly breeding conditions are optimum.

INFLUENCE OF WEATHER.—Ants did not work under certain temperature and moisture conditions. When the sun was shining the ants did not cross unshaded ground; from 9:00 A.M. to 3:00 P.M. the unshaded ground was hot enough to kill ants which were forced to pass over it. When there was no shade, clouds, or showers to keep the ground cool, the ants remained underground. The tunnels built by the fire ants were only about $\frac{1}{8}$ inch below the surface of the ground and were not deep enough to protect them from the heat of the surface soil. The ants were not noticeably affected by the sun in the area where these tests were run because the ground was well shaded with grass and trees. The ants worked in greatest force during the night.

The ants did not work when it was raining. Thus, when it rained at night during the peak of fly pupation, a substantial number of fly larvae penetrated the ground and pupated. In the third and fourth tests of the 2,000-egg series a comparatively large number of adult flies emerged because it rained most of the night during the period of heaviest pupation (Table 1). The majority of the larvae usually left the container at night, making them vulnerable to ant attacks. The high humidity at night allowed the larvae to wet the side of the container and crawl to the ground to pupate.

THE FIVE SPECIES OF ANTS.—*Pheidole subarmata borinquensis* Whlr. is about 2.0 mm. long and dark brown in color. The species is a common one but is not relatively abundant in Puerto Rico (Smith 1936). One small nest containing only a few workers and soldiers was located in the unprotected cage. The workers attacked house fly larvae but were unable to kill the larvae without assistance from the large soldiers 4.0 mm. in length. The larvae were then dragged into the nest and consumed. This species was observed to avoid *Solenopsis geminata*, but did not avoid the other three species attacking the fly population.

Tapinoma melanocephalum (F.), "albaricoque," is approximately 2.0 mm. long and has a black head and thorax with a whitish gaster. There are large numbers of this species over the island (Wolcott 1948). This species was abundant in the unprotected cage. Its nest was in a crevice between two boards on the cage. In addition to carrying off house fly eggs and first stage larvae, these ants were seen killing one newly emerged *Callitroga* sp. which wandered into an ant nest located on the side of a coconut palm tree. This species would avoid the fire ant, but not the three other species of ants attacking the flies.

Solenopsis corticalis Forel is about 1.5 mm. long and light brown in color. Over the island, its colonies are scarce (Wolcott 1948). However, it was found to be abundant in the unprotected cage, and had a nest between the base of the cage and the ground. These ants were not afraid of any of the other four species of ants and were the only ones which worked in the same area with the fire ants. They were observed to attack the fire ants when molested, although they were always finally driven away from any food the fire ants desired. In addition to destroying house fly eggs and pupae, this species was observed entering the puparia of *Phaenicia* spp. and consuming the pupae within.

Paratrechina longicornis (Latr.), the crazy ant, or "hormiga loco" is approximately 4.0 mm. long and shiny black with long legs and antennae. It occurs in great num-

bers over most of Puerto Rico (Wolcott 1948). Crazy ants were abundant at the test area, and were seen attacking and killing the larval and adult stages of *Musca domestica*, *Phaenicia* spp., *Callitroga macellaria*, and *Sarcophaga* spp. This ant depends upon strength and numbers to overcome its prey, since it cannot kill by stinging. The tremendous speed of the crazy ants made them effective in catching newly emerged adult flies. They were found to avoid the three species of ants thus far mentioned, and were especially intimidated by fire ants. The crazy ants, however, would attack and drag away a single fire ant trying to steal their food.

Solenopsis geminata (Fabr.), the fire ant, or "hormiga brava" is about 3.5 mm. long and dark brown in color. It is the most abundant species of ant in Puerto Rico (Wheeler 1908, Wolcott 1952). This ant was also the most numerous species in the unprotected cage. This species was seen attacking and killing the larval and adult stages of *Musca domestica*, *Phaenicia* spp., *Callitroga macellaria*, and *Sarcophaga* spp. One large colony was located 4 feet from the unprotected cage and another smaller colony was located in one corner of the cage. Both colonies had their nests in protective cover of patches of tall, dense grass. The mounds of earth piled over the nest were never higher than 6 inches, and usually averaged from 1 to 2 inches in height because of the washing effect from frequent showers. Wherever this ant stung a house fly larva a black spot approximately 1.0 mm. in diameter developed. As few as two stings paralyzed a house fly larva. The twice-stung larva could still pupate and wherever the larva had been stung black concave areas showed on the puparium. The adult fly emerged from the stung puparia without noticeable effects. A larva stung six or more times died. The fire ants drove away all ant competitors from the source of food and even attacked other fire ants from the smaller colony.

Fire ants are aggressive and would not hesitate to attack any animal. In a little over an hour, they killed four young birds (*Coerebaportoricensis*) which had fallen near the ant nest from a tree. The fire ant has been observed killing young rats, and is presumed to be capable of killing very young mongooses (*Herpestes auropunctatus auropunctatus*) in their burrows (Pimentel, 1955). The aggressiveness of the fire ant probably has prevented many other species of ants from increasing in number in Puerto Rico, and in some cases may have reduced the numbers of some other species of ants (Wheeler 1908, Wolcott 1952).

SUMMARY.—The ecological relationship of ants to the suppression of populations of *Musca domestica*, *Phaenicia* spp., *Callitroga macellaria*, and *Sarcophaga* spp. in Puerto Rico was studied. Under fly breeding conditions simulating those found in garbage cans in urban areas, ants destroyed 91 per cent of the potential fly population between the egg and adult stages. The fire ant, *Solenopsis geminata*, was the most important ant in the biological control of house flies, accounting for the majority of the flies destroyed. *Paratrechina longicornis*, *Solenopsis corticalis*, *Tapinoma melanocephalum*, and *Pheidole subarmata borinquensis* also killed some flies. Observations on the biology of *S. geminata*, *P. longicornis*, *S. corticalis*, *T. melanocephalum*, and *P. subarmata* were recorded.

REFERENCES CITED

Abbot, W. S. 1925. A method of computing the effectiveness of an insecticide. Jour. Econ. Ent. **18**(2): 265–7.

Phillips, J. S. 1934. The biology and distribution of ants in Hawaiian pineapple fields. Univ. of Hawaii, Exp. Sta. Pineapple Prod. Coop. Assoc. Limited. Bul. **No. 15**: 1–57.

Pimentel, D. 1955. Biology of the Indian mongoose in Puerto Rico. Jour. of Mammalogy. (in press)

Smith, M. R. 1936. The ants of Puerto Rico. Jour. of Agr. Univ. P. R. **20**(4): 819–75.

Wheeler, W. M. 1908. The ants of Porto Rico and the Virgin Islands. Bul. Amer. Museum of Nat. Hist. **24**(6): 117–58.

Wolcott, G. N. 1952. Personal communication of October 8, 1952.

Wolcott, G. N. 1948. The insects of Puerto Rico. Jour. Agr. Univ. P. R. **32**(4): 749–946.

Flight Dispersal of Rice Field Mosquitoes in Arkansas[1]

K. D. QUARTERMAN, J. A. JENSEN, WILLIS MATHIS, and WILLIAM W. SMITH

Interest in the control of rice field mosquitoes has grown steadily with the increased production of rice in Arkansas and other rice-producing areas of the United States. A knowledge of the flight habits of these mosquitoes is fundamental to an intelligent approach to the problem of their control. As a part of an overall study of the biology and control of rice field mosquitoes, Horsfall (1942) made some investigations on their flight habits, using field-collected adult mosquitoes, and dye as a marking agent.

The studies reported herein represented the initial effort of the Arkansas State Board of Health and the U. S. Public Health Service to gather more detailed data on the flight habits of the rice field mosquitoes, *Psorophora confinnis* Lynch-Arribalzaza and *P. discolor* Coquillett. The site selected for the release point for marked mosquitoes in these studies was approximately 1 mile west of the small town of Almyra, Arkansas, in the important Grand Prairie rice-producing section of the state.

MARKING METHODS.—Early fourth instar larvae were collected from nearby rice fields and transferred to small rearing vats. Radioactive phosphorus was added to the vats as a marking agent at a rate of approximately 0.1 microcurie of P-32 per ml. of water. Based upon the work of other investigators (Thurman & Husbands 1951, Pro-

[1] Contribution from the Communicable Disease Center, Public Health Service, U. S. Department of Health, Education and Welfare, Savannah, Georgia. Accepted for publication September 13, 1954.

Table 1.—Estimated numbers of radioactive rice field mosquitoes, *Psorophora* spp., marked and released in flight dispersal studies near Almyra, Arkansas, July–August, 1952.

Date Released	Number of Marked Adults Released	Stage of Development in Which Tagged	Cumulative Total Number Released
July 25	3,000	Larval	3,000
30	30,000	Larval	33,000
31	5,000	Larval	38,000
August 1	4,500	Adult	42,500
2	1,500	Adult	44,000
3	1,500	Adult	45,500
4	4,500	Adult	50,000

vost 1952) it was hoped that the marked mosquitoes could be mass-produced by rearing the larvae in the vats at concentrations of approximately 3 per ml. of water. In a preliminary test run without the addition of P-32, it was found that such a concentration of larvae in the vats resulted in extremely high mortality. The larval concentration was therefore reduced to approximately 1 per ml. for the first rearing in the presence of P-32. No food was added to the vats in this first rearing test. The water used in the vats was taken from the rice fields where the larvae were collected. From a total of approximately 300,000 larvae introduced into the vats on July 22, only about 3,000 adult nosquitoes were produced, most of which were males and were only weakly radioactive. These were released on July 25, 1952.

A second lot of about 300,000 larvae were introduced into the vats on July 27 and 28. Numerous clumps of floating algae were added to these vats, since it had been noticed that the larvae appeared to be feeding on this material. The clumps of algae were disintegrated by larval feeding within 2 hours. Approximately 35,000 moderately radioactive adults were released from this rearing on July 30 and 31.

In view of this second failure to produce large numbers of adults by rearing them in the vats, and since there was no readily available supply of larvae in the rice fields in the vicinity of the release site at this time, an attempt was made to trap and tag adult mosquitoes. Approximately 80,000 adult nosquitoes were trapped on the night of July 31, using conventional New Jersey mosquito light traps (Mulhern 1942) placed over eight large screened cages instead of the usual killing jars. Food in the form of 10 per cent honey in water to which P-32 was added at the rate of 1 microcurie per ml. of honey-water, was placed in the cages in small containers with cotton pads. The cages were held outdoors and examined at about noon on August 1. At that time, it was estimated that only about 5,000 mosquitoes had survived. These were released at that time, and a small sample of them taken as the mosquitoes left the cages indicated approximately 90 per cent were well marked with P-32.

Approximately 80,000 adults were trapped on each of the next 2 nights, similarly marked, and released before sunrise on the mornings of August 2 and 3. Survival was estimated at approximately 30 per cent on each of these dates, but samples of released adults indicated only about 6 per cent were effectively tagged. A fourth lot of 80,000 adults were trapped on the night of August 3 and were held under a cover of wet canvas, with the cages placed over vats of water to keep the humidity high and protect the mosquitoes from direct sunlight. These were held until about noon on August 4 and then released. Again the survival was only about 5,000 mosquitoes, of which approximately 90 per cent were tagged.

Table 1 summarizes the dates of release and approximate numbers of tagged mosquitoes produced in this study.

RECOVERY RESULTS.—For the recovery of the tagged mosquitoes, the mosquito populations in the surrounding area were sampled by operating conventional mosquito light traps at farm units in the area up to about 6 miles around the release site. A total of 40 traps was operated, nine of which were concentated in the town of Almyra.

The trap catches were removed daily, except in a few instances when rains made some of the roads impassable. The individual trap catches varied from 0.1 pint to over 3 quarts of mosquitoes daily. The heaviest catches were taken at those farm units where livestock were housed or pastured nearby. Based on the identification of representative samples of the trap catches in Almyra, the mosquito population in the area during this study period was composed of approximately 73 per cent *Psorophora confinnis*, 25 per cent *P. discolor*, and 2 per cent other species. The first tagged mosquito, a *P. confinnis*, was recovered in trap catches for the night of July 30 in one of the traps at Almyra about 1 mile east of the release point. Only 25 of the 40 trap catches were recovered for this date, due to bad weather. On July 31, two tagged mosquitoes were taken in a trap $\frac{1}{4}$ mile west of the release point and one in a trap approximately 4.5 miles east of the release site across heavily wooded land over 1 mile in depth. All were *P. confinnis*.

Detailed data on the recovery of tagged mosquitoes are given in tables 2 and 3. A total of 39 tagged *Psorophora confinnis* and 5 *P. discolor* were recovered in 16 different traps. Marked *P. discolor* were recovered in only three different traps—three specimens were in the trap located $\frac{1}{4}$ mile west of the release point and one each in traps at Almyra approximately 1 and 1.5 miles east of the release point, respectively. Marked *P. confinnis* were re-

Table 2.—Recovery of tagged specimens of *Psorophora* spp. in flight dispersal studies near Almyra, Arkansas, July–August 1952.

Date	Tagged Specimens Recovered		Traps in Which Tagged Specimens Recovered
	P. confinnis	*P. discolor*	
July 30	1	0	1
31	3	0	2
August 1	3	1	2
2	10	3	7
3	8	1	6
4	7	0	4
5	5	0	3
6	0	0	0
7	2	0	2
Total	39	5	16[a]

[a] Repeat catches of tagged specimens made in some traps. Tagged specimens recovered in only 16 different traps.

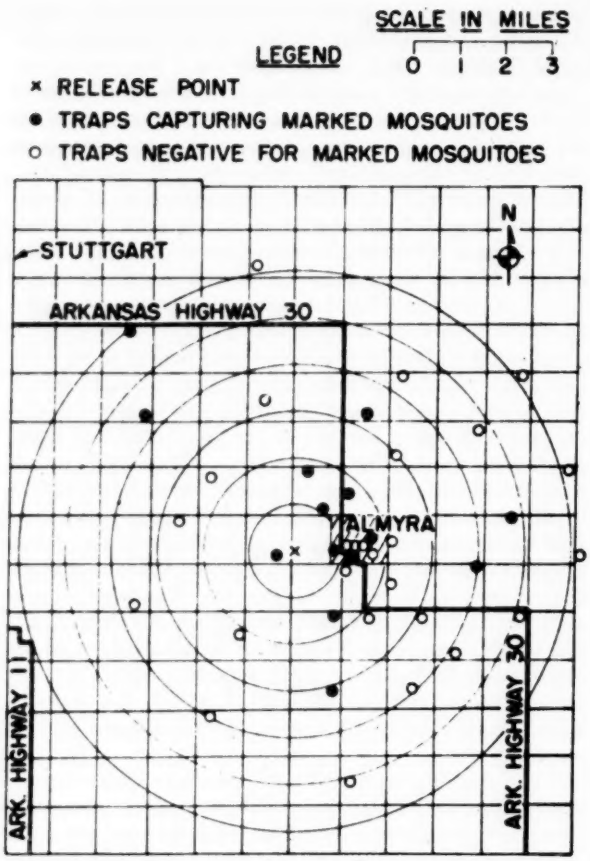


FIG. 1.—Flight dispersal of rice field mosquitoes marked with P-32 near Almyra, Arkansas. July–August, 1952.

covered in 15 different traps in many directions from the release point for distances up to about 6 miles, the maximum distance at which the traps were operated. Recoveries of tagged *P. confinnis* were made in two traps located east of the release point across a heavily wooded area over 1 mile in depth.

In considering the recovery of the marked mosquitoes (Table 3) relative to the distance of recovery from the release point, consideration must be given to the fact that the areas within 2 miles of the release point were more intensively trapped than those farther removed. If the averaged number of marked mosquitoes recovered per trap in the respective 1-mile zones were multiplied by a correction factor to equalize all traps on the basis of land area served, the results would indicate that roughly one-third of the tagged mosquitoes dispersed within the first 1-mile zone around the release point, one-third in the second 1-mile zone, and about one-third in the remaining area up to 6 miles from the release point. Since the mosquitoes were dispersed over larger areas as the distance from the release point increased, the density of the tagged mosquitoes naturally decreased.

Table 3.—Recovery of marked mosquitoes at indicated distances from the release point near Almyra, Arkansas, July–August, 1952.

Miles from Release Point	Traps Operated	Tagged Specimens Recovered	Average per Trap
0 –1	2	16	8
1.1–2	11	22	2
2.1–3	6	0	0
3.1–4	6	2	0.33
4.1–5	8	3	0.38
5.1–6	3	1	0.33
6.1–7	4	0	0
Total	40	44	1.1

While recoveries were made in all major directions (Figure 1) except southwest from the release site, most of them were in traps located in easterly and northerly directions from the release point. During most of the study period, the wind appeared to be blowing predominantly in these directions.

SUMMARY.—Using field-collected mosquitoes which were tagged with P-32 in the larval and adult stages, preliminary studies were made on the flight habits of rice field mosquitoes, *Psorophora* spp., in the Grand Prairie section of Arkansas.

Efforts at mass-rearing of field-collected early fourth instar *Psorophora* larvae for tagging with P-32 met with scant success, probably due to lack of adequate food. Efforts at holding wild *Psorophora* adults in screen cages for tagging with P-32 were likewise only partially successful.

Marked rice field mosquitoes dispersed in many directions from the release point, but tended to move mostly with the wind. *Psorophora confinnis* traveled at least 6 miles and traversed heavily wooded areas over 1 mile in width. *P. discolor* was recovered up to 1.5 miles from the release site, but the number of specimens of this species tagged and recovered was too low to provide significant information on its flight habits.

ACKNOWLEDGMENTS.—The authors gratefully acknowledge the assistance of Mr. John E. Taylor and the Arkansas State Board of Health in supplying automotive equipment and personnel to operate the traps used in these studies.

REFERENCES CITED

Horsfall, William R. 1942. Biology and control of mosquitoes in the rice area. Ark. Agr. Exp. Sta. Bull. No. **427.**

Mulhern, T. D. 1942. New Jersey mechanical trap for mosquito surveys. N. J. Agr. Exp. Sta. Cir. **421.**

Provost, M. W. 1952. The dispersal of *Aedes taeniorhynchus.* I. Preliminary studies. Mosquito News **12**(3): 174–90.

Thurman, D. C., Jr., and R. C. Husbands. 1951. Preliminary report on mosquito flight dispersal studies with radioisotopes in California, 1950. CDC Bulletin (U. S. Public Health Service), April 1951, pp. 1–9.

Water Relations of Cockroach Oöthecae[1]

LOUIS M. ROTH and EDWIN R. WILLIS, *Pioneering Research Laboratories, U. S. Army Quartermaster Research and Development Center, Natick, Massachusetts*

The eggs of the cockroaches *Blattella germanica* (L.) (Patten 1884), *Blaberus craniifer* Burm. (Nutting 1953), and *Diploptera dytiscoides* (Serv.) (Hagan 1951) increase in size during embryonic development. It is well known that the eggs of some insects (e.g., grasshoppers) absorb water from the environment (Buxton 1932, Wigglesworth 1950). However, the water relations of cockroach eggs have not been studied in detail although the importance of water in the development of the eggs of the German cockroach has been indicated (Ross 1929, Parker & Campbell 1940). We are studying the water relations of the oöthecae of several species of cockroaches, and herein present data from four representative species with three different types of ovipositional habits.

OVIPOSITIONAL TYPE 1.—The oötheca is carried by the female for only a short time after formation, frequently being deposited and abandoned within 24 hours.

Blatta orientalis L.—During embryonic development about fifteen per cent of the initial weight of the oötheca may be lost. The proportion of water in the oötheca remains fairly constant throughout development (Figure 1), as both water and solids are lost at about the same rate, but the water content of the eggs actually increases during development (Table 1). During the early stages of embryonic development the outside of the eggs and the inside of the oötheca are very moist. As development proceeds these surfaces become progressively drier, but the inner surface of the chorion and the embryo itself remain moist. Evidently during development water is absorbed by the egg from the inner surface of the oötheca. At the time of its formation, the oötheca is obviously moist. The water which is later picked up by the eggs is undoubtedly the water which was initially present in the oötheca outside the eggs.

The oötheca of *Blatta orientalis* is covered with a material which retards the loss of water. So effective is this

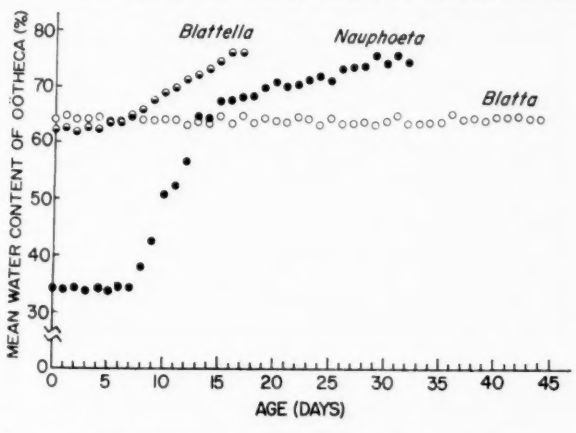


FIG. 1.—Water content of the oöthecae of 3 species of cockroaches. (Temperature, 27° to 29° C.)
○ = *Blatta orientalis* (343 oöthecae).
● = *Nauphoeta cinerea* (348 oöthecae).
◒ = *Blattella germanica* (385 oöthecae).

Table 1.—Variation with age in water content of eggs of *Blatta orientalis*.[a]

AGE OF EGGS (DAYS)	MEAN WEIGHT (MG.) Wet	Dry	MEAN WATER CONTENT ±S.E.[b] (PER CENT OF WET WEIGHT)	NUMBER USED Eggs	Oöthecae
12	6.80	2.50	62.9±0.34	22	13
18	7.00	2.43	65.2±0.34	19	10
21	7.15	2.34	67.2±0.26	31	22
26	7.28	2.29	68.5±0.14	24	17
33	7.45	2.14	71.4±0.42	9	5

[a] One or more eggs were dissected out of an oötheca, cleaned, weighed and then dried. We did not succeed in dissecting out eggs which were younger than 11 days because the chorious adhered to the inner walls of the oötheca; eggs older than 33 days were difficult to remove without rupturing the chorions which had become dry and brittle.
[b] S.E. = standard error.

substance that eggs hatched about 46 days later from oöthecae which had been kept in an atmosphere of 0 per cent relative humidity from the age of less than 1 day. The rates of weight loss of oöthecae subjected to abrasion or rinsing in water and drying are compared with the rate of loss from untreated oöthecae in figure 2. The respiratory ducts in the keel of the oötheca, because of their small connections with the outer air, allow a minimum of water to be lost from the eggs. It is likely that most of what little water is normally lost by untreated oöthecae escapes through the respiratory ducts, rather than through the wall of the oötheca. According to Pryor (1940) the oötheca of *B. orientalis* is covered with an oily secretion probably derived from the cuticle of the mother. The cuticular wax on the body of the cockroach seems to be secreted in a solvent which evaporates slowly keeping the wax greasy (Beament 1951). The cuticular grease retards water loss from the cockroach at normal temperatures; when the insect is exposed to slightly higher temperatures (e.g., *Periplaneta americana* at 35° C.), there is an abrupt rise in the loss of water following a change in the physical properties of the grease (Ramsay 1935). The effect of temperature on the weight loss of the oöthecae of *B. orientalis* is shown in figure 3. This temperture experiment indicates that the water proofing material on the oötheca is not the same as the mobile grease on the body of the cockroach; otherwise, one would expect a sudden increase in water loss at temperatures lower than 60° C. Beament (1945) found that the critical temperature of the cuticular grease of *B. orientalis* is about 30° C. *in vitro*.

Periplaneta americana (L.).—In laboratory colonies the American cockroach frequently eats part or all of the keels of recently deposited oöthecae. Almost invariably the eggs in these damaged egg cases fail to hatch and usually fail to develop into recognizable embryos because of the rapid loss of water. The effect of removing

[1] Accepted for publication September 16, 1954. Throughout this paper use of the term oötheca implies both the egg case and its enclosed eggs.

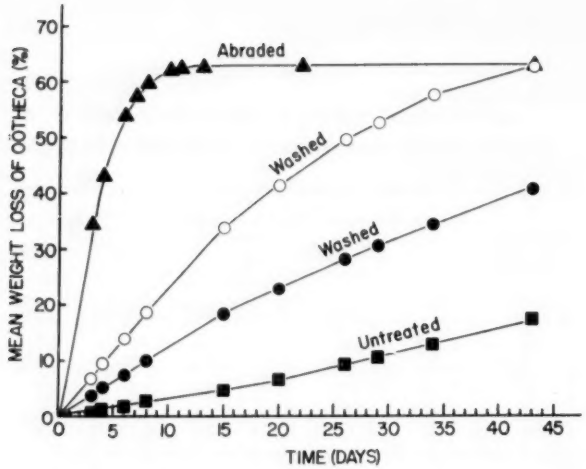


FIG. 2.—Effect of abrasion and rinsing the oöthecae of *Blatta orientalis* on weight loss.
■ = 8 untreated oöthecae (eggs hatched).
● = 4 oöthecae that were dipped in distilled water and wiped dry (87 to 100% of the eggs in the oöthecae completed development but did not hatch).
○ = 10 oöthecae that were dipped in distilled water and wiped dry (none of the eggs completed development).
▲ = 20 oöthecae that were gently abraded on No. 2/0 Crystal Bay Emery cloth (none of the eggs developed).
All oöthecae were less than one day old at the time of treatment. Temperature, 27° to 28° C.; Relative Humidity, 30 to 35%. The difference between the 2 groups of oöthecae that were dipped and wiped dry (solid and open circles) may have resulted from variation in the extent to which the oöthecae were rubbed dry; the 4 oöthecae in which eggs developed were undoubtedly least damaged by wiping.

the keels on the hatching of eggs in oöthecae kept at a low or high humidity is shown in table 2. The loss in weight of oöthecae lacking keels is compared with that of intact egg cases in figure 4. The membranes of the recently-laid egg retard water loss poorly, and one of the principal functions of the oötheca in this species, as in *B. orientalis*, is protection of the eggs from drying.

OVIPOSITIONAL TYPE 2.—The oötheca is carried externally by the female until or shortly before the eggs hatch.

Table 2.—Effect of removing the keels from oöthecae on hatching of the eggs of *Periplaneta americana*.

Condition of Oöthecae	Age (Days) at Time of Treatment	Number of Oöthecae Used	Number of Oöthecae in Which Eggs: Hatched	Developed but Did Not Hatch	Did Not Develop	Per Cent Eggs per Oötheca Which Hatched[a]
Oöthecae kept at 15% relative humidity						
Normal	<1	16	14	1	1	92
Keels removed	<1	20	0	0	20	—
Normal	14	20	13	4	3	93
Keels removed	14	20	0	0	20	—
Oöthecae kept at 90% relative humidity						
Keels removed	<1	20	1	4	15	—
Normal	3–6	24	22	1	1	97
Keels removed	3–6	18	10	5	3	87
Normal	16	20	20	0	0	99
Keels removed	16	20	18	0	2	99

[a] Based only on oöthecae from which eggs hatched.

Table 3.—Weight loss of detached oöthecae[a] of *Blattella germanica*.

Condition of Oöthecae	Number Used	Weight Loss (%) ±S.E.[b] After 24 Hours
Normal	8	30.5±1.96
Sealed with beeswax		
Posterior half	10	28.9±0.86
Anterior half	10	1.8±0.34

[a] All oöthecae were 5 days old when detached from the females and were kept at 28° C. and 17 to 30% R. H.
[b] S.E. = standard error.

One end of the oötheca is in close contact with the female for the duration of embryonic development.

Blattella germanica (L.).—The variation with age in the amount of water in oöthecae of the German cockroach is shown in figure 1. During embryonic development the oötheca acquires additional water from the body of the female. Ross (1929) and Parker & Campbell (1940) predicated that the wall of the oötheca in contact with the female's genital pouch must be permeable to water. The anterior end of the oötheca, held by the female, is lighter in color and not as sclerotized as the posterior part. We demonstrated a difference in permeability of the two regions of the oötheca by sealing, with beewax, the anterior or posterior halves of manually detached oöthecae and measuring weight loss. The results are shown in table 3. Further proof that the two ends of the oötheca vary in permeability was shown by keeping either the anterior or posterior ends of detached oöthecae on filter paper wet with distilled water. After 15 hours, 15 oöthecae that had had their anterior ends in contact with the water had gained 8.3 ±0.86 per cent in weight; 14 oöthecae that had had their posterior ends touching the water had lost 6.1 ±0.61 per cent in weight. The humidity was high in the covered petri dish in which

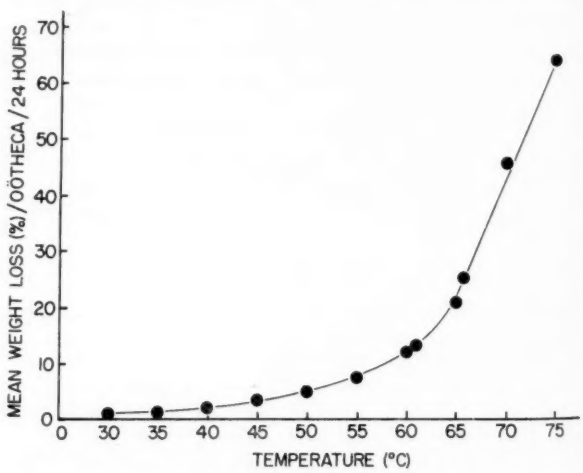


FIG. 3.—Weight loss of oöthecae of *Blatta orientalis* as a function of temperature. Oöthecae less than a day old were placed individually in tubes containing pellets of $CaSO_4$ (Drierite); the tubes were immersed for 24 hours in constant temperature water baths. Plotted points are means of data from 10 to 15 oöthecae (total for all tests 170).

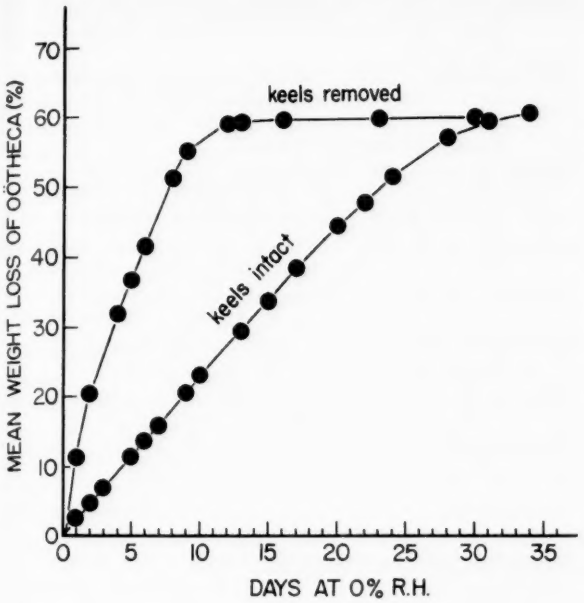


FIG. 4.—Effect, on weight loss, of removing the keels from oöthecae of *Periplaneta americana*. Fifteen treated and 10 untreated oöthecae, less than 1-day old, were used. Temperature 27° to 28° C. None of the eggs developed.

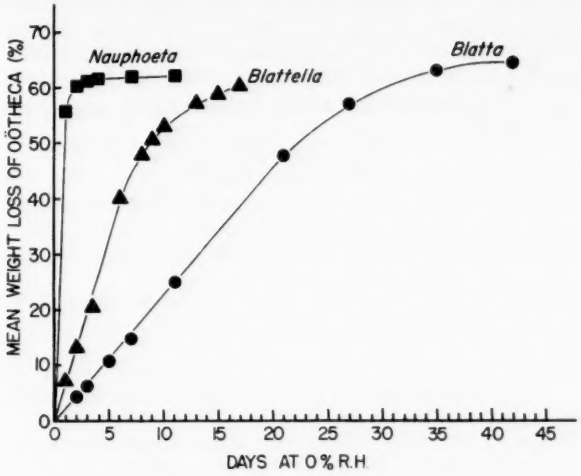


FIG. 5.—Weight loss of the oöthecae of 3 species of cockroaches.
● = 10 oöthecae of *Blatta orientalis* less than 1 day old.
▲ = 10 oöthecae of *Blattella germanica*, 1 to 2 days old when detached from the females.
■ = 4 oöthecae of *Nauphoeta cinerea*, about 2 weeks old when removed from the females.
All oöthecae kept at 0% relative humidity and 27 to 28° C. None of the eggs completed development.

these oöthecae were kept; yet in spite of this, oöthecae with their anterior ends not in contact with water lost weight.

OVIPOSITIONAL TYPE 3.—The completed oötheca is retracted into a brood sac, inside the female's body, where the eggs are incubated until hatching (Chopard 1950, Roth & Willis 1954).

Nauphoeta cinerea (Oliv.).—The initial water content of the oötheca and eggs of this species is low compared to that of *Blatta* or *Blattella*. The water content remains constant at about 34 per cent for 7 days, increases markedly for a week, and then rises more gradually until at hatching time the oötheca may contain about 75 per cent water (Figure 1). There was no indication of any gain in solids; the amount of dry matter in the eggs decreased gradually with embryonic development.

WATER LOSS THROUGH OÖTHECAE.—The öothecae of the above cockroaches differ as markedly as the three types of ovipositional behavior. The egg cases of *Blatta orientalis* and *Periplaneta americana* are hard and normally impermeable. The anterior end of the egg case of *Blattella germanica*, which is in contact with the oöthecal cavity of the female, is relatively soft and permeable to water. The oötheca of *Nauphoeta cinerea* is very soft, thin, may not cover the eggs completely, and presumably is permeable. The comparative losses in weight of oöthecae and eggs kept in a dry atmosphere are shown in figure 5. The eggs of *Nauphoeta*, the ovoviviparous species, lost practically all of their water within 2 days; the eggs of *Blatta* lost water most slowly, taking about 5 weeks to dry; *Blattella* eggs lost water at a rate intermediate between the other species. The three types of oöthecae differ in their ability to prevent desiccation of the eggs; the difference is correlated with oöthecal structure.

Data on the water relations of the eggs of other cockroaches, viz., *Supella supellectilium* (Serv.), *Blattella vaga* Heb., *Pycnoscelus surinamensis* (L.), *Leucophaea maderae* (F.), and additional data on the eggs of *Periplaneta americana* will be reported elsewhere.

SUMMARY.—Some of the water relations of the oöthecae and eggs of the following species of cockroaches have been studied:

Blatta orientalis (which does not carry its egg case during embryonic development): The oötheca loses water and solids at about the same rate. During embryonic development, however, the eggs actually pick up water from the moist inner surface of the oötheca. The oötheca is covered with a water proofing material which differs from the mobile grease on the body of the insect.

Periplaneta americana (which does not carry its egg case): Eggs frequently fail to develop in oöthecae with damaged keels because of the rapid loss of water. However, eggs 3 or more days old in oöthecae with damaged keels had a high hatching rate when kept at 90 per cent relative humidity but at 15 per cent none hatched.

Blattella germanica (which carries its egg case externally): During embryonic development the eggs acquire additional water from the body of the female. The anterior end of the oötheca which is in contact with the female is permeable to water, whereas the posterior end is not.

Nauphoeta cinerea (which carries its egg case internally): The water content of the eggs increases rapidly after the first week of embryonic development. By hatching time the water content has more than doubled. Dry matter decreased during embryonic development.

Differences in the oöthecae of the above cockroaches are consonant with the insects' ovipositional behavior.

Oöthecae of *B. orientalis* and *P. americana* are hard and normally impermeable. The anterior end of the oötheca of *B. germanica* is soft and permeable. The oötheca of *N. cinerea* is soft, thin, and presumably permeable. The three types of oöthecae differ widely in their ability to prevent desiccation of the eggs.

References Cited

Beament, J. W. L. 1945. The cuticular lipoids of insects. Jour. Exp. Biol. **21**: 115–31.

Beament, J. W. L. 1951. Wax secretion in insects. Nature **167**: 652–3.

Buxton, P. 1932. Terrestrial insects and the humidity of the environment. Cambridge Phil. Soc. Rev. Biol. **7**: 275–320.

Chopard, L. 1950. Sur l'anatomie et le developpement d'une blatte vivipare. Eighth Internat. Cong. Ent., **1948**, Stockholm, pp. 218–22.

Hagan, H. R. 1951. Embryology of the viviparous insects. The Ronald Press Co., New York. 472 pp.

Nutting, W. L. 1953. Observations on the reproduction of the giant cockroach, *Blaberus craniifera* Burm. Psyche **60**(1): 6–14.

Parker, B. M., and F. L. Campbell. 1940. Relative susceptibility of the ootheca and adult female of the German cockroach to liquid household insecticides. Jour. Econ. Ent. **33**(4): 610–4.

Patten, W. 1884. The development of Phryganids, with a preliminary note on the development of *Blatta germanica*. Quart. Jour. Micr. Sci. **24**: 549–602.

Pryor, M. G. M. 1940. On the hardening of the cuticle of insects. Proc. Roy. Soc., London. **128B**: 393–407.

Ramsay, J. A. 1935. The evaporation of water from the cockroach. Jour. Exp. Biol. **12**: 373–83.

Ross, H. H. 1929. The life history of the German cockroach. Trans. Ill. State Acad. Sci. **21**: 84–93.

Roth, L. M., and E. R. Willis. 1954. The reproduction of cockroaches. Smith. Misc. Coll. **122**(12): 1–49.

Wigglesworth, V. B. 1950. The principles of insect physiology. 4th Ed., Methuen, London. 544 pp.

Insects on Corn and Teosinte in Guatemala[1]

Reginald H. Painter, *Kansas State College, Manhattan*

Available evidence suggests that somewhere in middle America or central western South America primitive man domesticated corn (*Zea mays* L.). But little information is published on the insects affecting corn in this region (McKelvey & Osorio A. 1949; Melhus & Harris 1949, Viale & Humberto 1950). An opportunity was afforded me by Dr. I. E. Melhus[2] to study corn insects in Guatemala, Central America, in August, 1951 and again in August, 1952. The chief problem for study concerned the resistance of strains of corn to insect attack. Some results of this study have been reported (Melhus *et al.* 1954) but a number of incidental observations reported here were made on the occurrence and biology of corn insects. Among the insects chiefly associated with corn, collected or reared, and sent to specialists for identification only a few more than 50 per cent could be identified to species. This partially indicates the paucity of knowledge of the insects that occur on this important crop in the area where corn may have been first domesticated.

In this report, for the most part, only forms identified to species have been included and a number of species seen on corn but not feeding on the plant were not even collected. Specimens on which this report is based have been deposited at the Iowa State College-Guatemala Tropical Research Center, Antigua, at Kansas State College, Manhattan, and in collections of those who identified the material.

The non-domesticated plant nearest related to corn is teosinte, *Euchlaena mexicana* Schrad., which is native in Guatemala (Melhus & Chamberlain 1953) and Mexico. Insects were collected in naturally occurring areas of teosinte near Progreso, Department of Jutiapa, and on plantings of teosinte at Antigua, Cuyuta, and Tiquisate. Most but not all of the insects collected on teosinte were found also on corn. In general, insects appeared to be less common on teosinte where it was found in its native habitat at Progreso than elsewhere.

Most of the observations and collections were made at the trial grounds of the Iowa State College-Guatemala Tropical Research Center near Antigua, Sacatepequez (elevation 4953 ft.), where many strains of corn were under test along with varieties of other crops such as beans, alfalfa, kenef, teosinte, and a number of vegetables.

Besides Antigua, the following were the localities in Guatemala and dates where most of the other collecting was done:

Coban, Alta Verapaz, El. 4331 ft, Aug. 9, 10, 1951
Finca Barcena, National School of Agriculture, Guatemala, El. 4855 ft, Aug. 19, 24, 1951, Aug. 11, 1952
Finca Pintio, southwest of Antigua Aug. 21, 1952
Cuyuta, Esquintla, El. 50 ft., Aug. 27, 1951
Tiquisate, Esquintla, El. 220 ft., Sept. 5, 1951
Progreso, Jutiapa, El. 3000 ft. Sept. 10, 1951
Quetzaltenango, Quetzaltenango, El. 7690 ft. Aug. 16, 1952
Finca San Francisco, near San Jose Pinula, Guatemala, El. 6500 ft. Aug. 26, 1952.

Corn variety tests were located at several of these places so there were available a range of types, dates of planting, and plant maturities on which insects could be collected. The periods spent in Guatemala were Aug. 7 to Sept. 14, 1951, and Aug. 8 to Sept 1, 1952.

Notes on Species Collected.[3]—

[1] Contribution No. 633 Department of Entomology, Kansas Agriculture Experiment Station, Manhattan. Accepted for publication October 20, 1954.

[2] My thanks are due Dr. Melhus, formerly Director, Iowa State College-Guatemala Tropical Research Center, Antigua, not only for making the trip possible but for permitting the use of the corn varieties being grown and providing means for study of the insects collected. My thanks also are due for the many hospitalities extended by Mrs. I. E. Melhus and for help from other members of the staff especially Dr. Iris M. Chamberlain. Mr. Harold E. Box and Dr. Ray F. Smith made many useful suggestions in addition to identifying the species of *Diatraea* and *Diabrotica* collected.

[3] The author is indebted to the following individuals who made identifications of the specimens collected in Guatemala. Many of these specialists are on the staff of the Entomology Research Branch, Agr. Res. Service, U.S.D.A. Anderson, W. H.; Arnett, R. H.; Baker, E. W.; Beamer, R. H.; Box, H. E.; Burks, B. D.; Capps, H. W.; Chapin, E. A.; Clarke, J. F. G.; Field, W. D.; Foote, R. H.; Franclemont, J. G.; Gurney, A. B.; Hoff, C. C.; James, M.; Krombein, K. V.; Lane, M. C.; Metcalf, Z. P.; Morrison, H.; Muesebeck, C. F. W.; O'Neill, K.; Russell, L. M.; Sabrosky, C. W.; Sailer, R. I. Smith, M. R. Smith, R. F.; Stehr, W. C.; Stone, A.; Todd, E. L.; Vogt, G. B.; Walkley, L. M.; Warner, R. E.; Wheeler, M. R.; Wirth, W. W.; Young, D. A.

ORTHOPTERA

BLATTIDAE

Pseudomops intercepta (Burmi.) (Det. A.B.G.). Coban, one specimen collected on corn Aug. 9, 1951.

TETTIGONIIDAE

Anaulacomera denticauda S. & P. (Det. A.B.G.). Progreso, Jutiapa, one specimen collected on teosinte Sept. 10, 1951.

DERMAPTERA

FORFICULIDAE

Doru lineare (Esch.) (Det. A.B.G.). This earwig was perhaps the commonest insect on corn from an elevation of about 6000 ft. to near sea level. It was especially common at Antigua and Tiquisate and appears to be a predator or scavenger. On one occasion, a large earwig was seen feeding on the body of another individual of the same species. Females of this species often lay eggs and care for their young within burrows of the stalk borers, *Diatraea* spp. This species has been reported from various localities from the southern United States into South America.

THYSANOPTERA

THRIPIDAE

Frankliniella williamsi Hood (Det, K.O'N.). Corn and teosinte seedlings at Antigua were severely damaged by this species in August. In a limited test, DDT at 4 lbs. per 100 gal., aldrin and dieldrin each at 4 oz. per 100 gals. all gave good control and stopped the damage by this insect.

HEMIPTERA

MIRIDAE

Collaria oleosa (Distant) (Det. R.I.S.). This species was abundant on teosinte at Antigua, present on teosinte and corn at Progreso Jutiapa, on corn at Tiquisate and Antigua, and on teosinte at Tiquisate. There was no easily apparent damage done by the feeding of this insect. Eggs were thrust through the leaf sheath of corn in groups of 4 to 9. Nymphs were seen especially on young corn and teosinte. This species is reported from Mexico and possibly also California. Two species of this genus are known to feed on grasses in the United States.

REDUVIIDAE

Castolus plagioticollis Stal. (Det. R.I.S.). This species was present feeding on insects on corn at Cuyuta Aug. 27, 1951 and at Tiquisate Sept 5, 1951. At the latter location, one was caught feeding on a Lampyrid.

TINGIDAE

Leptodictya tabida (H.S.) (Det. R.I.S.). Present on teosinte at Tiquisate. Sept. 5, 1951.

LYGAEIDAE

Blissus leucopterus insularis Barber (Det. R.I.S.). A single specimen colllected on rice, Tiquisate, Guatemala, Aug. 6, 1951. None was seen on corn or teosinte at any location.

PYRRHOCORIDAE

Largus cinctus (H.S.) (Det. R.I.S.). Five specimens were collected on corn at Tiquisate Sept, 5, 1951.

COREIDAE

Leptoglossus zonatus Dallas (Det. R.I.S.). This species was rather common on corn at Tiquisate and at Antigua. Adults only were seen.

Zicca taeniola Dallas (Det. R.I.S.). Three specimens collected on teosinte at Tiquisate, Sept. 5, 1951.

PENTATOMIDAE

Galgupha quadrisignata (Stal) (Det. R.I.S.). Three specimens collected on teosinte at Tiquisate, Sept, 5, 1951.

Padaeus irroratus (H.S.) (Det. R.I.S.). One specimen, San Jose Pinula, on corn Aug. 26, 1952.

Padaeus trivittatus Stal. (Det. R.I.S.). One specimen on corn, San Jose Pinula, Aug. 26, 1952. Dr. Sailer suggests that this species may be the same as *P. irroratus*.

Pangaeus sallei Signoret (Det. R.I.S.). One specimen, Antigua, Aug. 8, 1952 on corn.

Podisus sagitta (F.) (Det. R.I.S.). Two specimens collected on corn, Antigua, Aug. 8, 1952.

HOMOPTERA

CICADELLIDAE

Carneocephala dyeri (Gibs) (Det. D.A.Y.). Three specimens collected on teosinte planted at Antigua.

Cuerna mexicana Oman and Bmr. (Det. D.A.Y.). One specimen collected on teosinte planted at Antigua, Aug. 27, 1952.

Dalbulus (*Baldulus*) *maidis* (De L. and Wolc.) (Det. D.A.Y.). Antigua, six specimens collected on corn and sugar beets. Aug. 8–28, 1952. This species is known to transmit the virus causing corn stunt (Barnes, 1954), a disease occurring in Guatemala (Melhus 1953).

Draeculacephala soluta Gibs (Det. D.A.Y.). Antigua, on corn, Aug. 8, 1951; Antigua, on teosinte Sept. 4, 1951.

Erythrogonia jucunda (Walk.) (Det. D.A.Y.). One specimen collected on corn at Coban Aug. 9, 1951.

Homalodisca centrolineata (Signoret) (Det. D.A.Y.). One of the commoner leafhoppers on corn and teosinte, especially toward the latter part of August. Twenty-one specimens of this variable species were collected at Antigua both years and seen at several other localities.

Keonolla dolobrata (Ball) (Det. D.A.Y.). Antigua, Aug. 8, 1952, one specimen collected on corn.

Oncometopia obtusifrons (Fowler) (Det. D.A.Y.). One specimen collected on teosinte, Progreso, Jutiapa, Sept. 10, 1951.

AREOPODIDAE (DELPHACIDAE)

Peregrinus maidis (Ashm) (Det. R.H.B.). One specimen collected at Tiquisate Sept. 6, 1951, on corn. This species has been reported to transmit the virus causing corn mosaic of Hawaii and the corn stripe disease of Cuba.

CIXIIDAE

Bothriocera tinealis Burn (Det. D.A.Y.). One specimen collected on corn, Tiquiste, Sept. 6, 1951.

DERBIDAE

Anotia invalida Fowler (Det. Z.P.M.). Collected in fair numbers at Tiquisate on teosinte Sept. 5, 1951. Dr. Metcalf reported that an undescribed species of *Anotia* was among the specimens collected along with *A. invalida*. Planthoppers of this family were common at Cuyuta and Tiquisate on teosinte planted there, and also were seen on corn growing nearby.

Neocenchrea gregaria Fennah (Det. D.A.Y.). One specimen collected on teosinte, Tiquisate. Sept. 6, 1951. This species was described in 1944 from Trinidad, W. I., and had been collected on *Cordia cylindrostachya*.

APHIDIDAE

Aphis maidis Fitch (Det. L.M.R.). The corn leaf aphid was observed in nearly all corn fields visited including those near Quetzaltenango at about as high an altitude as corn is commonly grown. Generally in Guatemala the colonies were not as large nor the numbers of infested plants so great as has been observed in the United States, although this may be true only of the particular month and years in which the observations were made. Infestation records taken on varietal plantings at Barcena suggested that certain inbreds from Guatemala corns were more susceptible than others. The actual specimens identified came from Antigua and Quetzaltenango.

Rhopalosiphum prunifoliae (Fitch) complex. (Det. L.M.R.). Aphids belonging to this complex were found in large colonies near the base of corn at Coban, Aug. 9, 1951. They were attended by ants, *Solenopsis geminata* (F.) which had constructed earthen sheds over some of the aphid colonies. In other cases, colonies of the aphids were unattended by ants.

COCCIDAE

Orthezia acapulcoa Morr. (Det. H.M.). Several specimens were collected on teosinte at Progreso, Jutiapa, Sept. 11, 1951.

COLEOPTERA

CARABIDAE

Leptotrachelus testaceus puncticollis Bates (Det. W.C.S.). On Sept. 1, 1951, pupae of this species were collected behind leafsheaths while examining stalks for infestation by *Diatraea*. One adult emerged Sept. 12. On Aug. 22 at Antigua 40 burrows of *Diatraea* were examined and 9 larvae, presumably of this species, and 2 pupae were found in the burrows. An adult of this species later emerged from one of these pupae. The larvae were common enough at Antigua to be an important factor in control of the stalk borers.

Onypterygia famini Sobir (Det. W.C.S.). These active green carabids were seen searching for and feeding on larvae of the fall armyworms at Barcena, Aug. 19, 1951. The species was also collected at Antigua, Aug. 27, 1952.

ELATERIDAE

Glyphonyx propinquus Champ. (Det. M.C.L.). Two specimens were collected on corn, Antigua, Aug. 18, 1952.

Horistonotus rufiventris Cand. (Det. M.C.L.). Twelve specimens of this species emerged Aug. 19–30 from cages placed over corn stubs in early August 1952. Adults have been collected on corn and teosinte at Antigua and seen on corn in other locations. The larvae probably feed on corn roots since the sand wireworm, *H. uhlerii* Horn, a species of this genus, is known to be injurious to crops in southeastern United States (Tenhet & Howe 1939).

THROSIDAE

Drapetes taeniolalus Horn (Det. R.H.A.). Two specimens were collected on teosinte planted at Tiquisate, Sept. 5, 1951.

SCARABAEIDAE

Anomala nitidula Bl. (Det. E.A.C.). One specimen collected at tip of corn ear, Barcena Aug. 24, 1951, apparently feeding on silks.

Anomala undulata Melsh. (Det. E.A.C.). Three specimens of this "blossom anomala" were taken on ears of corn at Coban Aug. 9. In later planted corn the silks had been severely eaten and this species was one of the several insects responsible for the damage.

Euphoria vestita G. & P. (Det. E.A.C.). Antigua, 1951, one specimen collected on corn.

Gymnetis cineria G. & P. (Det. (E.A.C.). This species was commonly feeding on silks of corn at Barcena Aug. 19, 24, 1951. Those in charge of experiments there had complained about white grub damage to young corn. This species may have been the one involved.

CERAMBYCIDAE

Dendrobias mandibularis (Serv.) (Det. R.H.A.). One specimen collected on corn, Tiquisate Sept. 5, 1951.

CHRYSOMELIDAE

Diabrotica and related genera (Det. R.F.S.). The groups of rootworms which are of high economic importance in Guatemala are discussed in detail in another paper (Melhus *et al.* 1954) where information on biology and a search for resistance in corn are treated in detail. The list of species given here is taken from that paper and includes those adults found feeding on tender leaves, silks, or tassels as well as on some other crops:

Acalymma cornuta (Baly). Antigua (corn).
Acalymma trivittata (Mann.). Antigua (corn).
Amphelasma carum carum (Say). Antigua (corn).
Andrector atrofasciatus (Jacoby). Antigua (corn, beans, teosinte). Most common on beans.
Diabrotica adelpha Harold. Antigua (corn, beans, teosinte, alfalfa); Coban (corn, tacomate); Barcena (corn).
Diabrotica balteata LeConte. Antigua (corn, beans, teosinte); Barcena (corn) Tiquisate (corn).
Diabrotica lepida (Say). Antigua (corn).
Diabrotica nigrofasciata Jacoby. Antigua (corn, beans). Most common on beans.
Diabrotica porracea Harold. Antigua (corn, teosinte); Barcena (corn); Coban (tacomate); San Jose Pinula (corn); S. Maria de Jesus (corn).
Diabrotica rufomaculata Jacoby. Antigua (corn).
Diabrotica sexmaculata Baly. Antigua (corn, beans).
Diabrotica tibialis Jacoby. Antigua (corn).
Diabrotica tricolor Jacoby. Antigua (corn).

"*D. balteata* was the only species of this group seen on the Pacific costal plain; *D. porracea* was the last species to disappear in corn fields above about 6,500 feet." In addition three undescribed species or subspecies were present on corn.

Disonycha sp. (Det. W.H.A.) A species of this genus with greenish blue elytra and yellow thorax was seen commonly on corn at Antigua and 10 specimens emerged in cages placed over corn stubs in the ground during August, 1951. These cages were placed for collecting *Diabrotica* that had fed on corn roots (Melhus *et al.* 1954). The larvae of the species may have fed on nearby weeds earlier in the year.

Monelepta sp. (Det. W.H.A.). This small brown leaf beetle was responsible for much damage to silks of corn at Barcena Aug. 19, 1951, where the insect occurred in large numbers. It was only slightly less abundant at Antigua early in August each year. A callow adult was dug from under a corn plant and one emerged from a cage placed over corn stubs at Antigua (Melhus *et al.* 1954).

CURCULIONIDAE

Catolethrus longulus Boh. (Det. R.E.W.). One specimen collected on corn, Antigua, 1951.

Cleistolophus similis Chev. (Det. R.E.W.). Several adults collected on corn at Finca San Francisco near San Jose Pinula Aug. 26, 1952. Several mating pairs were seen.

Epicaerus capteillensis Sharp. (Det. R.E.W.). One specimen collected on corn at Antigua, 1951.

Geraeus. Some of the curculionid larvae that were collected at several places are thought possibly to belong to this genus because of the frequency of the adults on corn and because Dr. W. H. Anderson of the Entomology Research Branch identified the larvae as belonging to the tribe Limnobarini to which this genus belongs. Some of these larvae were found burrowing in fairly mature corn stalks or in buds of seedlings; others where feeding in ears on kernels in the hard dough stage; and still others were burrowing in the brace roots or were dug from soil under corn plants. The last two groups are capable of doing severe damage to corn in Guatemala. Adults were not definitely connected with either of the groups of larvae.

Species of this genus have been reported to infest the stems of grasses. Blackwelder (1947) lists *senilis* under *Geraeus* but the other species discussed here were placed in the genus *Centrinaspis* Casey. Here, the latter are listed as they were identified. Of the group, only *tonsilis* has not previously been reported from Guatemala.

Geraeus perscitus (Hbst.) (Det. R.E.W.). Antigua, one specimen emerged Aug. 14, 1952 in a cage that had been placed over a corn hill to catch emerging insects.

Geraeus podagrosus Champ. (Det. R.E.W.). Antigua, Aug. 31, 1952. One specimen collected on corn.

Geraeus pugnex (Boh.) (Det. R.E.W.). Three specimens emerged from larvae collected from soil under corn hills Antigua, Aug. 8, 1952.

Geraeus senilis (Gyll.) (Det. R.E.W.). This species was the most plentiful one found on corn. Specimens were identified from Antigua, Barcena, Coban, Cuyuta, San Jose Pinula, and Tiquisate. Although occurring from Aug. 10 to Sept. 6, the species was more numerous toward the latter part of August.

Geraeus tonsilis (Boh.) (Det. R.E.W.). Specimens were collected on corn at Antigua, Aug. 8, 31, 1952, and at Barcena Aug. 11, 1952. A specimen that may belong to this species was collected on corn at Progreso, Jutiapa, Sept. 10, 1951.

Sitophilus oryza (L.) (Det. R.E.W.). The common rice weevil was seen on a number of occasions crawling on the maturing ears of corn. The species is an important pest of stored corn in Guatemala.

LEPIDOPTERA

PHALAENIDAE (Noctuidae)

Chorizagrotis auxiliaris agrestis (Grt.) (Det. E.L.T.). One male emerged Sept. 3, 1952, in a cage placed over corn stubs at the Antigua trial grounds.

Enopyga crista (Walk.) (Det. J.G.F.). Coban. Reared from a larva collected on corn Aug. 9, 1951. It was feeding in a manner similar to the fall armyworm.

Heliothis armigera (Hbn.) (Det. J.G.F.). The corn earworm was far less common than anticipated. One adult and only three or four larvae were collected during the entire stay in 1951. The next year larvae of this insect were more plentiful. On Aug. 28, 1952, at Antigua larvae removed from ears at about roasting ear stage consisted of 21 corn earworm, 4 fall armyworm, 3 neotropical cornborers and one weevil larva. This insect appears to be much less injurious in Guatemala than in Kansas.

Laphygma frugiperda (J. E. Smith) (Det. J.G.F.; E.L.T.). By far the most conspicuous pest of corn in Guatemala was the fall armyworm, which in a measure takes the place of the less common corn earworm. The infestation of the fall armyworm varied considerably from place to place but individuals and evidences of damage were always easy to find. Three types of damage were done by this insect. Since the eggs are laid about the upper part of the stalk considerable feeding takes place in the whorl and on the developing tassel. Occasionally the bud may be cut off. Skeletonizing of the leaves in the whorl was done by the young larvae which, as they grew, cut larger holes through the leaves. The second type of damage consisted of gouging out areas in the stalks and ear shanks. This was done by the larger larvae and causes an amount of breakage to stalks roughly equal to that caused by the feeding of *Diatraea*. The third type of damage was similar to that done by corn earworm in feeding on the kernels in the developing ear.

The life history and seasonal history were not studied in detail, since the former is well known (Luginbill 1928, Hynes 1942, McKelvey & Osorio A. 1949). Both the larvae and adults are variable in appearance. The young larvae usually have two black spots present about one-fourth of the distance back from the front of the body. When full grown, the larvae pupate in the soil or under trash on the surface of the soil. The females are known to lay up to 5,000 eggs each in groups of 40 or more, in the whorl of the corn. Tachinid parasites, *Achaetoneura archippivora* (Wile) were reared from the larvae in considerable numbers and one Ichneumon fly was collected as a cocoon near the empty skin of a small armyworm. A green ground bettle, *Onypterygia famini* Sobier, was found at Barcena feeding on the larvae of the fall armyworm. In 1951, a heavy infestation in the variety plots at Barcena permitted records to be taken on the differing degrees of infestation. The results of these studies are reported elsewhere.

Table 1.—Specimens of *Diatraea* collected or reared to adult. Guatemala, 1951.

Localities	Date Collected	*Diatraea* Reared	
		saccharalis	*lineolata*
Coban	Aug. 9–10	14	1
Barcena	Aug. 19	0	11
Cuyuta	Aug. 27	12	present?
Finca Pintio[a] near Antigua	Aug. 21	3	present?
Near corn dryer and corn crib at Tiquisate	Sept. 5, 6	24	4

[a] From the appearance of the larvae and from adults reared in 1952, *lineolata* was the most abundant at the trial grounds, Antigua.

Peridroma margaritosa (Haw.) (Det. E.L.T.). One specimen of the variegated cutworm emerged from a pupa collected from soil under a corn hill, Antigua Aug. 8, 1952.

PYRAUSTIDAE

Scybalista cinera (Warr.) (Det. H.W.C.). Antigua, one larva collected on corn Aug. 21, emerged Sept. 3, 1951.

CRAMBIDAE

Diatraea lineolata (Wlk.) (Det. H.F.B.; H.W.C.). neotropical cornborer (Kevan 1943).

Diatraea saccharalis (F.) (Det. H.E.B.). sugarcane borer (Kevan 1943). The most abundant of the stalk borers in corn in Guatemala were larvae of various species of *Diatraea*. Adults of eight species of this genus have been recorded from Guatemala (Box 1948). At least two species were present and reared from larvae burrowing in the stalks of corn. The most common species reared was *Diatraea saccharalis* (Fab.), the sugarcane borer. This species is widely known as a pest of sugarcane throughout the American tropics. Larvae collected on sugarcane during the course of this study were reared. A larva believed to belong to this species was collected in a rice stem at Tiquisate.

The second most prominent species was *Diatraea lineolata* (Walk.), the neotropical corn borer. This species is closely related taxonomically to *Diatraea grandiosella* Dyar, the southwestern corn borer. *Diatraea lineolata* is primarly a pest of corn but has been reared from teosinte and occasionally on wheat, sugarcane, broomcorn, *Tripsacum laxum* and *T. australe* (Box 1951). These two species of *Diatraea* were not uniform in their distribution in the various corn fields visited (Table 1). *Diatraea lineolata* was greatly in the majority at Barcena; elsewhere, with the exception of the trial grounds at Antigua, *saccharalis* was the more common species.

Eggs. Eggs of both species was secured from moths collected at Tiquisate. Eggs that apparently belong to these species were seen at this same locality in a field of corn that was knee to shoulder high. Eggs were also seen on teosinte there. The neotropical corn borer lays round or oval masses of flat scale-like eggs. In the field, these occur mostly on the lower side of the upper leaves. The females readily laid their eggs not only on corn but on the sides of the plastic container in which they were confined. According to Kevan (1944) when the eggs are about 2 days old they develop bright red, transverse bands. Examples of such eggs were seen at Tiquisate. The sugarcane borer lays long slender egg masses with up to 122 eggs, along the midrib of the upper side or on the lower side of the upper leaves. Moths in captivity laid eggs readily on leaves but less readily on the sides of the plastic container. The eggs of *saccharalis* are reported not to develop the bright red bands but rather irregular reddish blotches.

Larvae. Young larvae presumably belonging to one of the species of *Diatraea*, probably *lineolata*, were found in the spiral leaf whorl of the corn at Tiquisate that carried the egg masses. These larvae had skeletonized the leaves similar to that done by young larvae of the European corn borer and the southwestern corn borer. Typical full grown specimens of larvae of the two species can be distinguished by their general appearance but it is probable that a good many individual larvae cannot be identified with certainty. Larvae of *saccharalis* are yellowish white with pale brown spots and a line of greyish lilac or pinkish blotches along each side of the dorsum. The larvae superficially resemble those of the European corn borer. The larvae of *lineolata* are larger, the spots are dark brown to black on an almost pure white ground color. The pink areas characteristic of *saccharalis* are present, but far less conspicuous. This neotropical corn borer has a white resting stage during which the spots are virtually absent. In this respect, it is similar to the southwestern corn borer. These white larvae occur mostly in dry or mature corn stalks in Guatemala and an adult *lineolata* was reared from one. According to Kevan (1944), such larvae require contact moisture before they will transform into the pupal stage. This type of white resting stage has not been reported for *saccharalis* in the American tropics.

Adults. The moths of *saccharalis* are generally smaller than *lineolata*. Dyar & Heinrich (1927) gave the wing spread for the males as 18 to 28 mm. and for the females from 27 to 39 mm. The ground color of the forewing is yellowish tan to brown. Small groups of black scales occur at the wing margins between the ends of the veins. Patches of black or dark brown scales form two broken bands diagonally across the wings. The front of the head is protruding and gently rounding (Box 1931, Fig. 2).

The moths of *lineolata* are generally larger than *saccharalis*. Dyar & Heinrich (1927) recorded the wing spread of the males as 20 to 31 mm., of the females as 26 to 40 mm. The ground color of the forewing is straw-yellow. All the wing veins are more or less margined with brown. The front of the head is conic in outline (Box 1931, Fig. 2). The hind wings of both species are whitish.

Damage. The damage done by tunnelling in the stalks is similar to that caused by the southwestern corn borer except that virtually no girdling occurs. The larvae of *saccharalis* occurred throughout the stalk including the peduncle of the tassel but were more common in the upper part of the stalk. They appeared to attack corn earlier than the neotropical corn borer did and in the heavier infestations seen at Coban often there had been more than one borer per internode. The larvae of *lineolata* tended to occur lower down on the stalk, rarely, even in the stalk below ground. Infestation of *lineolata* apparently occured later than the infestations of the sugarcane borer. Both species, but especially *lineolata*, attack the ears. The young ears or nubbins are reduced to rotting massses, apparently by pathogens introduced with the

larvae. Larvae have been found in the pith of more mature ears, and only rarely have either species been found to feed on the kernels.

Parasites, predators, and associated fauna. The eggs of *Diatraea* collected at Tiquisate were rather heavily parasitized, possibly by *Trichogramma minutum* Riley. Coccoons of *Apanteles diatraeae* Mues. (family Braconidae) were common in the burrows of *Diatraea*, especially at Coban. In that locality, they were eight times as common as the Muscoid puparia of a fly that apparently is parasitic on the larvae. These Muscoid puparia were particularly abundant at Antigua. A single species of Larvaevorid, *Paratheresia claripalpis* (Wulp), was reared from puparia collected at Antigua and Coban. The *Apanteles* was itself parasitized by a small hymenopterous insect, *Horismenus floridanus* (Ashm.), belonging to the family Eulophidae. Similarly, a small hymenopterous parasite, *Trichopria* sp., emerged in numbers from several of the Muscoid puparia.

A number of Arthropods that were probably predators on *Diatraea* were collected or reared. Larvae of at least one species of ground beetle (*Lepotrachelus testaclus punctcollis* Bates), were common and adults were reared from specimens collected at Antigua. Pseudoscorpions, *Lustrochernes reimoseri* Beier, live and raise young in the tunnels. An earwig, *Doru lineare* (Esch.), perhaps the commonest insect on corn in Guatemala, lays its eggs and cares for its young in burrows of these stalk borers. Both these latter forms are probably predacious. Arthropods found in fair numbers include species of mites, millipeds, Phoridae and Sciaridae. At least two species of ants take over burrows in older stalks for nests. A wild bee (Andrenidae) utilized an empty burrow for its nest.

EPIPASCHIIDAE

Pococera atramentalis Led. (Det. H.W.C.). Antigua. One pupa collected on corn Aug. 31, emerged as an adult Sept. 2, 1951. Another specimen emerged Aug. 20, 1952, in a cage placed over a hill of corn.

DIPTERA

STRATIOMYIIDAE

Artemita bellardii (G. T.) (Det. M.T.J.). Specimens of this species were fairly common on corn at Tiquisate, Sept. 5, 1951.

OTITIDAE

Eumecosomyia nubila (Wied.) (Det. W.W.W.; R.H.F.). This species was reared from decaying corn silk collected Aug. 8, 10, 1951, and from a corn bud infested by maize maggot, *Euxesta major* Wulp. It was also rather abundant on corn and teosinte planted at Antigua both years.

Euphara caerulea (Macq.). (Det. W.W.W.). One specimen was collected on corn, Tiquisate, Sept, 5, 1951. This is reported to be the first record in the U. S. National Museum from North of Panama.

Euxesta major v.d. Wulp. (Det. W.W.W.). This maggot is one of the most destructive insects on seedling corn in Guatemala. Many of the previous observations on the biology of the insect and its damage (Melhus & Harris 1949) have been confirmed and some additional observations made. The insect itself was collected either as larvae or adults at Antigua, Coban, and Progreso, and damage by the insect was seen elsewhere. As well as the earlier known habit of killing the bud, adults were reared from larvae collected in the base and tip of ears, a previously unrecorded type of damage. Adults were reared from larvae collected both on corn and teosinte. The wide variation in adult size did not appear to be related to the species of host. The difference in degree of infestation found in different varieties will be reported elsewhere.

Euxesta obliquestriata Hendel (Det. R.H.F.). Antigua one specimen collected on corn Aug. 21, 1952.

Euxesta schnusei Hendel? (Det. W.W.W.). Two specimens collected on teosinte, Antigua, 1951.

Euxesta sororcula (Weid.) (Det. W.W.W.). A fairly common fly collected on corn at Antigua, Tiquisate, Progreso, Jutiapa, 1951, 1952. Larvae collected from an ear at Antigua, Aug. 8, emerged as adults Aug. 27 to Sept. 7 1952. Next to *E. major* this is the most common species of the genus on corn, and also was abundant during the latter part of August on teosinte planted at Antigua.

Euxesta stigmatias Lw. (Det. R.H.F.). Two larvae collected in a corn ear at Antigua Aug. 8, emerged as adults Aug. 31, 1952. This species has been called the corn silk fly by Barber (1939) who recorded its occurrence and habits in Florida. It is also known from the West Indies, where it has been found feeding on silk of corn ears. The type specimens came from Cuba and Brazil.

Pterocalla costalis v.d. Wulp. (Det. W.W.W.). One specimen collected at Progreso, Jutiapa, on corn Sept. 10, 1951. This species was described from Mexico.

Senopterina cyanea (Giglio-Tos) (Det. W.W.W.). One specimen collected on corn, Tiquisate, Sept. 5, 1951.

CHLOROPIDAE

Oscinella magnicornis Duda (Det. C.W.S.). A puparium from a corn stalk Barcena collected Aug. 19, emerged as an adult later in August, 1951.

Oscinella nigronotata Duda (Det. C.W.S.). Antigua, one specimen collected as a larva in corn ear Aug. 10, emerged Aug. 30, 1952.

DROSOPHILIDAE

Drosophila nigricuria Patterson & Mainland (Det. M.R.W.). Larvae of this species were collected at Coban Aug. 10, 1951 in an ear of corn and emerged as adults a few days later. One larva collected in a *Diatraea* burrow produced an adult Aug. 27, 1951. This species was previously known from northern Mexico.

LARVAEVORIDAE

Achaetoneura archippivora (Will.) (Det. C.W.S.). In 1951, ten specimens of this species were reared from various larvae of the fall armyworm, principally those collected at Barcena. The species occurs over a considerable area of the southeastern United States.

Carcelia flavirostris (Wulp.) (Det. C.W.S.). Four adults emerged in two different cages placed over corn hills to catch emerging insects; Antigua, Aug. 27, 1952.

Paratheresia claripalpis (Wulp.) (Det. C.W.S.). Two specimens emerged from puparia collected in *Diatraea* burrows at Antigua and Coban in 1951. One specimen from a puparium collected from a corn stalk. Antigua Aug. 21, emerged Aug. 29, 1952. This parasite was not definitely associated with either species of *Diatraea* in

this study, but is known to parasitize several species including *D. saccharalis*.

Zelia vertebrata (Say) (Det. C.W.S.). One specimen was reared from a puparium collected from corn stalks, Antigua, 1951.

HYMENOPTERA

ARGIDAE

Sofus pilicornis (Holmgr.) (Det. B.D.B.). One male, two females, collected on corn, Antigua, Aug. 27, 28, 1952. The larval host is reported to be *Portulaca*.

BRACONIDAE

Aphaereta auripes (Prov.) (Det. C.F.W.M.). A single specimen emerged Aug. 19, 1952, in a cage placed over a corn hill, Antigua. This species is reported by Muesebeck *et al.* (1951) to parasitize various Diptera.

Apanteles diatraea Mues. (Det. C.F.W.M.). Cocoons of this species were easily found in burrows of *Diatraea* especially at Coban, and numerous individuals were reared. It was also reared from cocoons collected at Antigua. The species is known to parasitize several species of *Diatraea*.

DIAPRIIDAE

Trichopria sp. (Det. C.F.W.M.). This hyperparasite emerged from Muscoid puparia collected from the burrows of *Diatraea* in corn, Antigua, 1951.

EULOPHIDAE

Horismenus floridanus (Ashm.) (Det. B.D.B.). This species which also occurs in southeastern United States was reared from cocoons of *Apanteles diatraea* taken from the burrows of the corn stalkborers *Diatraea* at Coban Aug. 9, 1951.

FORMICIDAE

Solenopsis geminata (F.) (Det. M.R.S.). Ants of this species were attending aphids of the *Rhopalosiphum prunifoliae* complex at Coban, Aug. 9, 1951.

ACARINA

TETRANYCHIDAE

Tetranychus bimaculatus mullisetis McG. (Det. E.W.B.). Rather abundant on corn near Quetzaltenango Aug. 16, 1952 (7000 to 8000 ft.). Itonidid larvae were associated with the mites and apparently predacious on them. Spider mites were not seen in corn fields elsewhere. It is noteworthy that this spider mite was damaging corn at elevations where insect pests on corn were almost completely absent.

SUMMARY.—Among about 180 species of insects collected from or reared on corn in Guatemala, only about half could be identified to species by specialists in the various groups. These do not include immature forms collected, but not reared. In all, a total of 93 species were identified and are listed here. Eighty-one species were collected on corn, and 27 on teosinte, the most closely related species to corn. Of the species listed, 15 were found on both corn and teosinte. Twenty-eight of the species were reared from immature forms. When better known, the insects reared on corn and teosinte in this area may shed some light on the relationship and past history of these two plants.

The most destructive corn pests of the growing crop in Guatemala are species of *Diabrotica* and related genera, *Diatraea lineolata*, *D. saccharalis*, *Euxesta major* and *Laphygma frugiperda*.

REFERENCES CITED

Barber, G. W. 1939. Injury to sweet corn by *Euxesta stigmatias* Loew. in southern Florida. Jour. Econ. Ent. **32**: 879–80.

Barnes, Douglas. 1954. Biologiá, ecologiá y distributión de las chicharritas, *Dalbulus elimatus* (Ball) y *Dalbulus maidis* (DeL. & W.) Mexico: Sec. de Agric. y Ganaderia, Oficina Estud. Esp. Fol. Tech. **11**: 1–112.

Blackwelder, R. E. 1947. Checklist of the Coleopterous insects of Mexico, Central America, the West Indies and South America. Part 5. U. S. Nat. Mus. Bull. **185**: 765–925.

Box, H. E. 1931. The Crambine genera *Diatraea* and *Xanthopherne* (Lep., Pyral). Bull. Ent. Res. **22**: 1–50.

Box, Harold E. 1948. Notes on the genus *Diatraea* Guilding (Lepid., Pyral.) (Introductions and parts I, II, and III.) Entom. Venezolana, Bull. **7**: 36–59.

Box, Harold E. 1951. New species and records of *Diatraea* Guild. from northern Venezuela (Lepid., Pyral.) Bull. Ent. Res. **42**: 379–98.

Dyar, H. G. and C. Heinrich. 1927. The American moths of the genus *Diatraea* and allies. Proc. U. S. Nat. Mus. **71** (art. 19), #2691: 1–48.

Hynes, H. B. N. 1942. Lepidopterous pests of maize in Trinidad. Trop. Agr. Trin. **19**: 194–202.

Kevan, D. K. McE. 1943. The neotropical corn stalkborer *Diatraea lineolata* Walk. and the sugar cane moth borer *D. saccharalis* Fabr. as maize pests in Trinidad, with note from Grenada. Trop. Agric. **20**: 167–74.

Kevan, D. K. McE. 1944. The bionomics of the neotropical corn stalkborer *Diatraea lineolata* Walk. (Lep., Pyral.) in Trinidad B.W.I. Bull. Ent. Res. **35**: 23–30.

Luginbill, Philip. 1928. The fall armyworm. U. S. Dept. Agr. Tech. Bull. **34**: 1–91.

McKelvey, J. J., and F. J. Osorio A. 1949. Control del gusano cogollero del maiz. Mexico Sec. Agr. y Ganaderia, oficina Est. Esp., Fol. Divulgacion **6**: 1–16.

Melhus, Irving E., 1953. A preliminary study of the diseases of corn and some related hosts in Guatemala. Iowa State Col. Jour. Sci. **27**: 519–36.

Melhus, I. E., and I. M. Chamberlain. 1953. A preliminary study of teosinte in its region of origin. Iowa State Col. Jour. Sci. **28**: 139–64.

Melhus, I. E., and H. M. Harris. 1949. A new insect pest of maize in Central America. Iowa Agr. Exp. Sta. Res. Bul. **371**: 603–11.

Melhus, I. E., R. H. Painter, and F. O. Smith. 1954. A search for resistance to the injury caused by species of *Diabrotica* in the corns of Guatemala. Iowa State Col. Jour. Sci. **29**: 75–94.

Muesebeck, C. F. W., K. V. Krombein, and H. K. Townes. 1951. Hymenoptera of America north of Mexico. Synoptic catalog. U. S. Dept. Agr. Mon. **2**: 1–1420.

Tenhet, J. N., and E. W. Howe. 1939. The sand wireworm and its control in the South Carolina coastal plain. U. S. Dept. Agr. Tech. Bul. **659**.

Viale, Emilio, and Rosado E. Humberto. 1950. Chinche de la raiz del Maiz (*Cyrtomenus* Sp.) Turrialba **1**: 93–4.

A Method of Rearing Honey Bee Larvae *in vitro*[1]

A. S. Michael and M. Abramovitz, *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*

Inability to isolate larvae of the honey bee, *Apis mellifera* L., from the hive and to rear them away from adult bees under controlled laboratory conditions has long hampered the study of diseases of the brood. Investigators have been forced to use larvae in the hive with all the attendant difficulties resulting from natural infections, removal of larvae by adult bees, spread of disease outside the inoculated area, and age of larvae infected. It has therefore been highly desirable to devise a method of rearing larvae in the laboratory for this purpose.

Bertholf (1927) had some success in keeping larvae alive in the laboratory. When they were approximately 3 days old he transferred them from the hive to a small watch glass containing a 50-per cent sucrose solution. The watch glass was placed inside a petri dish containing a little water and the petri dish placed in an incubator at about 35° C. Larvae treated in this way remained alive up to about 60 hours. Unfortunately Bertholf gives no information as to whether any growth or development occurred.

Velich (1930), using larvae 4–5 days old, was able to carry them through to adults in glass boxes, Hansen cages, and Petri dishes at an incubating temperature of 33–35° C. Haydak (1939) reported success with a similar method. Von Rhein (1933) described a somewhat laborious method of rearing larvae by hand in an incubator.

However, all the foregoing work seems to have been successful only in degree, and each method had some rather serious shortcomings. Either the method was too laborious to be adapted to large-scale investigations or it was limited by the age of the larvae or the type of food required. Bertholf's method seemed to approach most closely the ideal, but had not been developed to an ultimate conclusion.[2]

An effort was therefore made to devise a more satisfactory method of rearing honey bee larvae in the laboratory for use in studies of brood diseases. Frames containing larvae 4–5 days old were brought into the laboratory, and after the cells had been covered with a thin film of wax to restrict the larvae to the cells, the frames were held in an incubator at 34° C. The larvae were able to spin cocoons and assume their normal position in the cells. On the 5th day the brood had reached the pupal stage. On the 13th day the pupae were almost fully pigmented and emergence as adults became a foregone conclusion.

It became apparent that the larvae could be handled and studied more conveniently if they were removed from the frames to artificial cells. Therefore, artificial cells were prepared by placing a layer of beeswax in the bottom of a petri dish, making a depression 3 to 4 mm. deep in the wax, and placing over each depression a 5- by 10-mm. glass cylinder. Each cell was thus approximately 5 by 13 mm. Capping was accomplished with a thin layer of lens tissue. Larvae from 2 to 5 days old were placed in the cells and fed upon honey. A platinum needle was used, as it was found that the larvae fed more readily in this way than from food placed in the base of the cell. Larvae 1 and 2 days old survived less than 2 days, but older larvae had an average survival time of 5.0 to 8.3 days. This was sufficient time for inoculation studies of European foulbrood. When a suspension of *Bacillus pluton* from infected larvae was fed to larvae 3 days old held in these cells, the average survival time was reduced to 2.6 to 3.0 days and *B. pluton* was demonstrated microscopically.

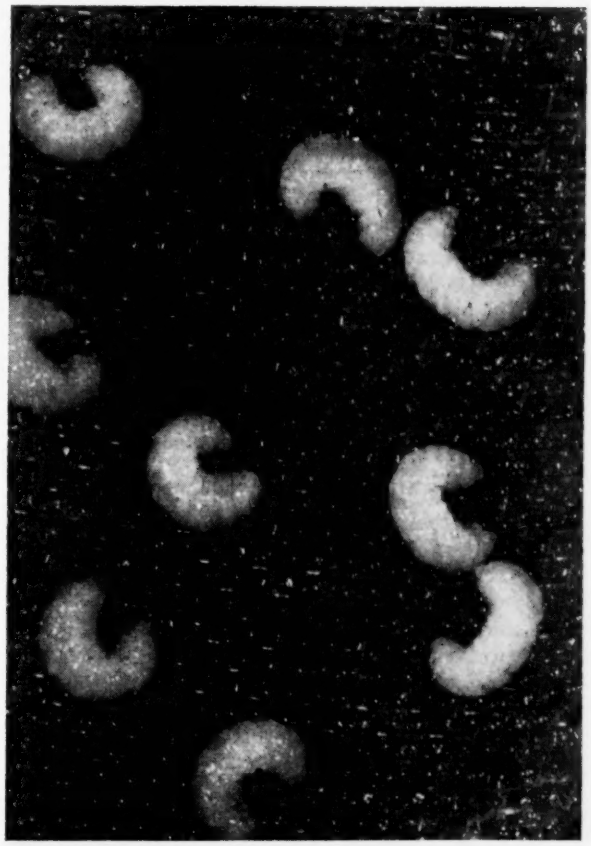


Fig. 1.—Honey bee larvae feeding through the plastic screening in the self-feeding dish.

The hand-feeding method was tedious, and honey by itself was an obviously inadequate food. Therefore, a method of continuous self-feeding with more adequate food was devised. A pad of absorbent cotton approximately $\frac{1}{4}$ inch thick, saturated with a water solution containing 25 per cent of honey and 10 per cent of dehydrated yeast extract, was placed in the bottom of a petri dish and covered with a piece of 12-mesh, 15-gauge plastic screening (Lumite cloth), which was pressed down in firm contact with the pad. The screening kept the larvae from drowning in the liquid food, which was readily accessible in the wells or interstices of the screening. As shown in figure 1, the larvae fed avidly and with apparent ease.

Larvae 3 days old were allowed to feed for 2 to 3 days

[1] Accepted for publication September 17, 1954.

[2] Weaver (1953 personal communication) has been successful in producing queen bees from worker larvae by a method of hand feeding.

Table 1.—Mortality of honey bee larvae 4 to 5 days old fed suspensions of *Bacillus pluton* and *Bacterium eurydice*.[a]

Suspension	Per Cent Mortality in		
	3 Days	4 Days	5 Days
B. pluton in honey	90	90	90
B. pluton and *B. eurydice* in honey	70	70	70
Honey	10	10	10
Water	20	30	30

[a] 5,000,000 organisms per milliliter of suspension.

and then transferred to petri dishes containing a thin layer of beeswax on the bottom. These larvae reacted normally, attempted to spin cocoons but produced pads of silk on the beeswax layers, progressed through pupation, and emerged as adult bees in approximately 14 days. The entire process of pupation, morphological development, and pigmentation was observed with ease. It was found advantageous to place a small pad of cotton in each petri dish, and moisten it daily to maintain a humid atmosphere.

Three-day-old larvae were hand-fed a suspension of *B. pluton* for inoculation purposes to assure ingestion of the infective material, and then placed in the self-feeding dishes. These larvae did not increase in length, although they seemed to feed as readily as the control larvae. Upon death they were examined and the presence of *B. pluton* in large numbers was demonstrated. None of these organisms were found in the control larvae. When the infective material was fed to older larvae just before they stopped feeding, they required no other care than proper temperature and humidity conditions. Thus larvae 4 to 5 days old placed in petri dishes containing a thin layer of beeswax, given one feeding by hand for inoculation purposes, and placed in an incubator were studied continuously and with ease as to the progress of the disease. The results of a typical test by this method are shown in table 1.

Summary.—A method of rearing honey bee larvae under controlled laboratory conditions has been devised by utilizing a self-feeding dish. A pad of absorbent cotton saturated with a liquid food is placed in a petri dish and covered with plastic screening. The larvae rest upon the plastic screening and feed through the interstices or wells of the screening. When the larvae cease feeding, they are transferred to petri dishes containing a thin layer of beeswax on the bottom, where they spin a pad of silk, pupate normally and emerge as adults.

By utilizing this method disease or development studies can be made in a continuous manner on a daily or hourly basis. Any stage or age of larva or pupa and the complete development cycle from larvae 3 days old through to the adult bee are made available for experimental observation.

European foulbrood can also be studied by utilizing the last portion of the larval cycle. If the infective material is fed to larvae 4 to 5 days old just before they cease feeding, the larvae require little care other than proper holding conditions.

References Cited

Bertholf, L. M. 1927. The utilization of carbohydrates as food by honey bee larvae. Jour. Agr. Res. **35**(5): 429–52.

Velich, A. V. 1930. Entwicklungsmechanische Studien an Bienenlarven. Ztschr. f. Wiss. Zool. **136**(2): 210–22.

Von Rhein, Werner. 1933. Über die Entstehung des weiblichen Dimorphismses im Bienenstaate. Wilhelm Roux. Arch. f. Entwickl. Mech. der Organ. **129**(4): 601–65.

Haydak, M. H. 1939. Food and development of the worker and the queen honey bee. Gleanings Bee Cult. **67**(12): 740–2, 776–7.

Parathion Residuals on Immature Peaches and the Hazard in Spraying and Thinning Operations[1]

P. E. Braid[2,3] and G. G. Dustan[4]

The use of parathion for the control of orchard pests has become general, and there has been a tendency to increase the concentrations applied, although the hazard of exposure to residual parathion under field conditions has not been clearly delineated. In the peach orchards of the Niagara district of Ontario, ill-effects supposedly due to residual parathion during thinning operations have emphasized the need for an evaluation of the dangers associated with orchard procedures. Therefore measures of the parathion residue loss have been followed in order to obtain an estimate of the diminution of the exposure hazard with time. Specifically, parathion residue loss on peach fruit has been determined during a 31-day period, starting in July. These studies have revealed that while air and leaf residuals decay rapidly to a safe level, the potential harzard from parathion on the immature fruit persists for a much longer period. It is concluded that the recommended safe time lapse between spraying and thinning of peaches embodied in the Ontario Spray Calendar of the Ontario and Canadian Departments of Agriculture should not be reduced.

Experimental Procedure.—Two experimental plots, designated as A and B, were sprayed with parathion in concentrations of 2.0 and 1.0 lb. of the 15 per cent wettable powder per 1000 lb. (i.e. per 100 Imperial gallons) of water, respectively. A third plot which received no spray was reserved as a control. The insecticide was applied from a small power sprayer at the rate of 3 to 4 (Imperial) gallons per tree. This machine delivered a coarse spray,

[1] Accepted for publication September 20, 1954.

[2] Chemist, Occupational Health Laboratory, Department of National Health and Welfare, Ottawa, Canada.

[3] The writer wishes to acknowledge the assistance of Mr. M. Patry in the analytical work.

[4] Officer-in-Charge, Laboratory of Entomology, Vineland Station, Ontario, Canada.

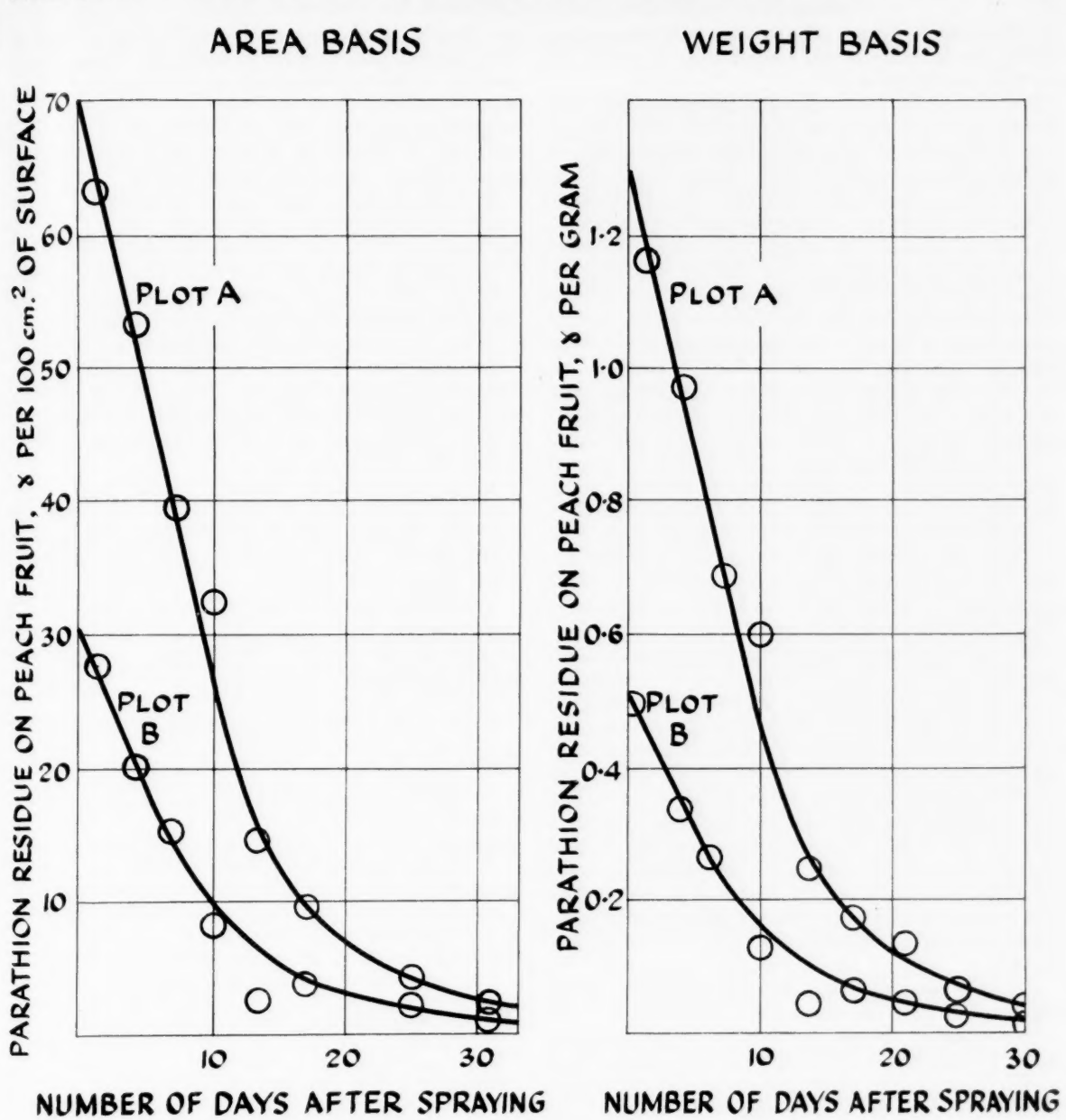


FIG. 1.—Decay of residue of parathion 15 per cent wettable powder applied to immature peach fruit. Plots A and B were sprayed at the rate of 3 to 4 Imperial gallons per tree with concentrations of 2 lbs. and 1 lb., respectively, per 1000 lbs. (100 Imperial gallons) of water.

but the total amount of parathion per tree was estimated to be approximately the same as that applied by commerical-type sprayers.

One-quart samples of the fruit were collected from each of the three plots at intervals and shipped to the Ottawa laboratory, where they were weighed, counted and extracted at once by the method of Jones & Riddick (1952). The samples were transferred to 1-quart mason jars and extracted with three portions (100 ml., 100ml., and 50 ml.) of iso-octane, the jar being capped with a tinfoil liner to avoid contamination of the solvent by rubber. The combined extracts were evaporated to 50 ml. volume and treated with three 100 ml. portions of acetonitrile in a separatory funnel. The combined acetonitrile extracts were evaporated and adjusted to a 15 ml. volume and a 3 ml. aliquot analysed for parathion by the semi-micro method of Wilson *et al.* (1951).

EXPERIMENTAL RESULTS.—The parathion concentration is commonly expressed in terms of sample weight. However, for our studies it was also desirable to express it in terms of surface. Surface areas were calculated for the samples by assuming sphericity and relating it to the number and size of peaches in the sample. Parathion residuals are shown graphically in terms of weight and

of surface area in figure 1. The average daily temperature during the sampling period ranged from 63 to 83° F., the total rainfall being 4.1″.

DISCUSSION OF RESULTS.—The initial surface concentrations on peach fruit are of the same order of magnitude as those found on (apple) foliage under equivalent spraying conditions (Braid *et al.* 1954). However, the initial rates of decay on peach fruit (4.2 and 2.2 micrograms/100 cm.²/24 hrs.) are far less than the corresponding rates associated with foliage, which ranged from 20 to 250 micrograms/100 cm.²/24 hrs. Consequently residues on foliage decreased very markedly within 38 hours to 10–20 micrograms/100 cm.². It is evident from an examination of figure 1 that peach fruit concentrations reach this level only after about 12 days. Furthermore, the initial rate of decay of residue on the fruit levels off to a much slower rate (0.2 to 0.4 micrograms/100 cm.² /24 hrs.), the point of intersection of the two rate slopes occurring at approximately 12 and 14 days for plots B and A, respectively. The corresponding point for curves depiciting residue on foliage occurs at approximately 2 days. The rates of decay given here are apparent rates, no correction having been made for the growth of the fruit. The slower rate of decay in the absence of rapid growth has been demonstrated by measurements of residue on peach bark (Bobb 1954).

The curves of figure 1 are qualitatively similar to those obtained by Barnes *et al.* (1950) and Fahey *et al.* (1952) for residues of parathion on mature peaches. However, there is considerable divergence among the values obtained by the above authors, by Walker (1950), and by ourselves, for both the initial concentrations of parathion on the fruit, and the rate of decay of the residue. These differences may be related to differences in climatic conditions, to the variety and maturity of the fruit, method of application of spray, number of previous sprays, and other factors. Consequently, the residue values given here may apply only to immature Elberta peaches under climatic conditions approximating those of the Niagara district.

The chief hazard in the Niagara peach orchards is associated with the practice of hand-thinning of the fruit, with consequent danger of absorption of parathion residues through the skin. Foliage and air residues decay rapidly to a low value after spraying an orchard, but the peristence of residue on the peach fruit is apparent. No safe limit for surface residue on peaches has yet, however, been promulgated. Therefore, no simple reference concentration is available which might be applied to the data of figure 1, in order to arrive at a safe time interval between spraying and thinning. However, considering that there is no thought of entering an orchard within 2 days of spraying with parathion and handling the foliage (except possibly for brief examination), and recalling that foliage concentrations at the end of 2 days are equivalent to those on peach fruit at the end of 12 to 14 days it does not seem advisable to reduce the 14-day waiting period recommended by the Department of Agriculture.

In 1953, the spray concentration recommended by the Canadian Department of Agriculture was 1.5 lbs.[5] 15 per cent wettable powder per 1000 lbs. water. At the end of 14 days, the residue on fruit when this concentration is used, would be approximately 10 micrograms per 100 cm.² With this higher concentration no ill-effects have yet been reported when the waiting period has been observed.

SUMMARY AND CONCLUSION.—For parathion spray application rates of 1 and 2 lbs. of 15 per cent wettable powder per 1000 lbs. (100 imperial gallons) of water, initial residues on immature peaches were 30 and 70 micrograms/100 cm.², respectively.

Initial rates of decay of residue on the fruit, for the above application rates, were 2.2 and 4.2 micrograms/100 cm.²/day. The initial rate of decay persisted for approximately 12 to 14 days, and subsequently levelled off to a lower value.

The 14-day waiting period (7, if protective clothing is worn) between spraying and thinning of peaches recommended by the Canadian Department of Agriculture should be retained for the present.

REFERENCES CITED

Barnes, M. M., G. E. Carmen, W. H. Ewart, and F. A. Gunther. 1950. Fruit surface residue of DDT and Parathion at harvest. Advances in Chem. Ser. **I**: 112-6.

Bobb, M. L. 1954. Parathion residues on peach bark and foliage. Jour. Econ. Ent. **47**(1): 190–1.

Braid, P. E., J. P. Windish, and C. R. Ross. Parathion spray concentrations and air and leaf residuals in Quebec apple orchards. (In press)

Fahey, J. E., D. W. Hamilton, and R. W. Rings. 1952. Longevity of parathion and related insecticides in spray residues. Jour. Econ. Ent. **45**(4): 700–3.

Jones, Lawrence R., and John A. Riddick. 1952. Separation of organic insecticides from plant and animal tissues. Anal. Chem. **24**(3): 569–71.

Walker, K. C. 1950. Parathion spray residue on soft fruits, apples and pears. Advances in Chem. Ser. **I**:123–7.

Wilson, C. W., Rodger Baier, Dale Genung, and James Mullowney. 1951. Estimation of 0,0-diethyl 0-p-nitrophenyl thiophosphate. Anal. Chem. **23**(10): 1487–9.

[5] 1.0 lbs. was previously recommended.

Life History of *Eotetranychus uncatus* Garman[1]

JAMES A. UBERTALLI

Recently there has been an increasing number of previously unknown, destructive spider mite species appearing in deciduous fruit orchards across the nation. The Garman spider mite, *Eotetranychus uncatus* Garman, is one of these newly recognized species that has come into prominence as an important pest of deciduous fruit trees in New England. It was originally identified by Dr. Philip Garman of the Connecticut Agricultural Experiment Station in 1949, has since been found well distributed in Massachusetts by Dr. E. H. Wheeler, and has been taken at several points in Connecticut.

The purpose of this paper is to present the results of life history studies of *Eotetranychus uncatus*, conducted at the Connecticut Agricultural Experiment Station during the summer of 1953. Limited field observations are included with the intent of presenting a general picture of the species relative to habits in the field.

FEEDING INJURY.—The Garman spider mite occurs on apple, causing severe damage to the foliage when abundant. It has been observed feeding upon Cortland, McIntosh, and Red Delicious varieties. All active stages feed upon the leaves of the host. Feeding is usually confined to the lower surface of the leaf, but in some cases it may take place on the upper surface. The actual feeding process is accomplished by the cheliceral stylets which penetrate the leaf tissue. The liberated plant fluids are sucked up by means of the oral orifice situated near the tip of the rostrum. The extraction of chlorophyll and other pigment results in a characteristic blotching or stippling of the foliage. E. H. Wheeler observed that, "In feeding on the undersurface (of the leaves) they seem to cause an uneven growth of the two surfaces of the leaf, thus causing a cupping or crinkling of the leaf from below. In heavy infestations the entire area along the two sides of the midrib and isolated areas on other parts of the leaf are affected in this way" (Pritchard & Baker 1952). These observations were verified by the writer. In addition, a typical "bronzing" of the foliage is a characteristic symptom of infestation. Severely attacked trees may become completely defoliated and devitalized, indirectly affecting the size of the fruit.

REARING METHODS.—The rearing of *Eotetrancyhus uncatus* was accomplished through the use of a modified "Munger cell," figure 1. The constituents of this cage were comprised of blotting paper, $\frac{1}{8}$ inch "plexiglass" strips, and rubber bands. The blotting paper and plexiglass strips were cut into pieces measuring 4 inches in length by 2 inches in width. Two holes were drilled in one-third of the plexiglass pieces to serve as cells. An undrilled plexiglass piece formed the base of the cage. A layer of blotting paper was placed on top of the plexiglass piece to a thickness of 1 inch. A fresh apple leaf was placed on the blotting paper, underside facing up, and a plexiglass piece with the two drilled cell holes was placed on the leaf, each hole exposing a small circle of the leaf. A male and a female mite were placed in each cell with the aid of a small camel's-hair brush. A solid plexiglass piece was placed on top of this, and the entire cage was held together with three rubber bands.

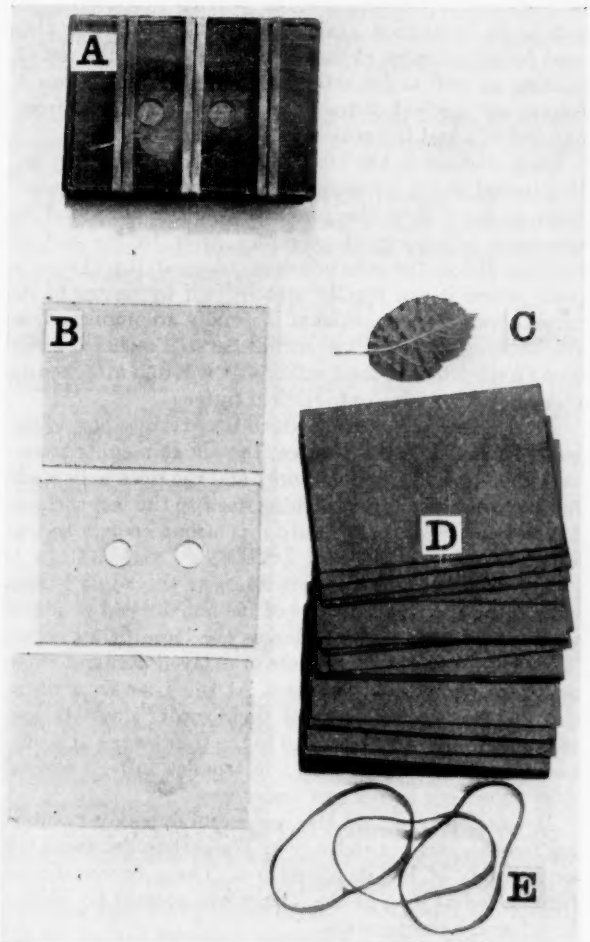


FIG. 1.—Constituents of the Modified Munger Cell. A. Assembled B. Disassembled, C. Leaf, D. Blotting Paper, E. Rubber Bands.

A leaf so confined remained fresh from 3 to 4 weeks if the blotting paper was wet every third day. The wet blotting paper retained enough moisture to keep the leaf from drying out.

Specimens of *Eotetranychus uncatus* were collected from apple leaves of the McIntosh variety. Females were separated for egg deposition studies. One male and one female were placed in each cell of the modified "Munger cell," and were held in a controlled temperature room at 80° F. Other cages containing males and females were placed in the insectary where they were held under natural conditions. Temperature readings were determined daily by means of a thermograph.

BIOLOGY.—Adult females spin a considerable amount of webbing. The silk spun by this species is very fine, and is worked into a regular net-like pattern over the circum-

[1] Abstract from thesis submitted in partial fulfillment of the requirements for the degree of Master of Science; University of Massachusetts, 1954. Accepted for publication September 21, 1954.

ference of the leaf. In addition, the deutonymphs also spin a web similar to that of the adult, although not as extensive. It is probable that the primary function of the web is for protection against enemies. The web is also used for attachment of tarsal claws preceding the act of molting as well as for attachment of eggs, and forms a convenient method of travel, enabling mites to go from one end of a leaf to another with amazing dexterity.

Each stadium in the life history is divided into an active period and a quiescent period. The period of quiescence is devoted to the formation of new parts and to necessary physiological processes prior to the actual molting. Before the mite becomes quiescent, it picks out a place where it can readily attach itself by means of its tarsal claws. The attachment is usually accomplished on the webbing or on the leaf surface, or in a secluded niche along a midrib. The mite extends its legs and attaches its claws to the webbing or to the leaf surface.

After a few days, during which time certain physiological changes have taken place, the old skin splits transversely across the cephalothorax and the mite pulls itself from the cast shell by attaching itself to the leaf surface. It rests and feeds awhile until it is strong enough to travel about.

Eotetranychus uncatus overwinters as the adult female entirely on the tree. Clusters of the females can be found under loose bark scales as far as the loose flakes occur. They become active at the late or delayed dormant stage of McIntosh bud development. At this time on a warm day the mites swarm out of their winter quarters and make their way over branches to the spur leaves. It seems necessary for the overwintering females to feed several days before egg laying gets under way.

It was observed that the species produces overwintering females early in October in Massachusetts, probably as a result of low temperatures. These overwintering females fed as long as the foliage was present no matter how low the temperature.

On three occasions mites were observed mating. The average time consumed in mating was 4 minutes. As a rule, the males completed their development a fraction of a day sooner than the females, insuring positive fertilization; the males awaiting the emergence of the females. The male crawled under the female from the rear, clasping his front legs about her abdomen. He curved his abdomen upward and forward until it met the tip of the female's abdomen. The pair remained in this position until the female was evidently fertilized. It was noted that fertilized females laid eggs which subsequently became females. Unmated females laid eggs which in turn produced males. From general observation it is believed that fertilization is not accomplished at each act of mating.

In a number of instances, it appeared that males required only one nymphal molt before reaching the adult stage. To clarify this discrepancy, several males were reared and observed twice daily for development. It was determined that in many cases during hot weather the males underwent two nymphal molts in a single day (Cagle 1949).

Eotetranychus uncatus, as in the case of all members of the family Tetranychidae, deposits eggs from which are hatched six-legged larvae. The larvae transform into eight-legged protonymphs which in turn become deutonymphs and finally adults. Each stage in the development of this mite is preceded by a period of quiescence and a single molt.

Egg.—The egg is spherical and measures about 0.12 mm. in diameter. It is clear and watery when first deposited, becoming opaque and pearly-white in color as incubation progresses. Just before hatching, the egg becomes straw-colored, the reddish eyespots of the embryo becoming quite distinctly visible. The egg is very similar to that of the two-spotted spider mite, *Tetranychus bimaculatus* Harvey, except for a very fine papilla or hair protruding from the center. The papilla measures approximately 0.7 mm. in length, tapering gradually to the tip, which is slightly curved or bent. The cast eggshell remains where it was at the time of hatching, maintaining much of its original shape. The discarded eggshells, together with cast larval and nymphal skins, are quite conspicuous on leaves that have been infested for any length of time.

Larva.—The larva when first hatched is round, approximating the size of the egg, and possesses six legs. At this time it is colorless, except for the reddish eyespots which are distinctly visible. Feeding takes place immediately, and the color changes to pale green with the exception of the cephalothorax and legs which remain colorless and semi-transparent. Several smallish black spots appear, four on each side of the abdomen.

Protonymph.—The protonymph differs from the larva in that it has eight legs. Eight black spots are present as in the larva, but are, as yet, inconspicuous. There is quite a variation in coloring, the following colors for mites of this stage being observed: dark green, yellowish-green, and lemon-yellow; the dark green color predominating. The protonymph is approximately 0.18–0.20 mm. long.

Deutonymph.—The deutonymph female is slightly larger than the protonymph, measuring 0.26–0.28 mm. in length. The ground color varies from yellowish-green to lemon-yellow. The spots are generally larger and more prominent, apparently being influenced by the food. Males are distinguished from females in this stage by the smaller size of the body and the pointed abdomen. The male is greenish-yellow to lemon-yellow in color, and the black spots are somewhat smaller than in the female.

Adult.—The adult male is much smaller and more active than the female. The body is narrow and the abdomen is distinctly pointed. The black spots on the abdomen are inconspicuous or absent. The aedeagus is long, attenuate and pointed, enlarged strongly at the base and undulate just beyond the middle, the tip extending somewhat beyond the end of the abdomen. The male measures from 0.29 to 0.32 mm. in length, by 0.15 mm. in width.

The adult female is more elongate than the common European red mite, and is flesh-colored or pale lemon-yellow, sometimes with a slight tinge of green. The winter form is distinctly yellow and sometimes bright green. The collar trachea is hooked and segmented more like *Tetranychus bimaculatus* than other members of this subgroup. The duplex setae, located on the tarsal segment of the first leg, nearly touch at the base. The palp has a strong hook extending slightly beyond the base of the

palpal thumb. The thumb is longer than wide. The small black spots are distinctly visible behind the eyes, usually eight in number.

LENGTH OF STAGES.—The incubation period of the eggs of *Eotetranychus uncatus* ranged from 2 days at an average temperature of 82° F. to 9 days at an average temperature of 69.8° F.

The larval period ranged from 2 to 6 days for males and from 1 to 6 days for females. The average temperature at which the 1-day stages occurred was 81.6° F., and that during the 6-day stages was 69.3° F.

The protonymphal period ranged from 2 to 6 days for males and 2 days for females. The average temperature of the 2-day stages was 81.5° F., and that during the 6-day stages was 74° F.

The deutonymphal period ranged from 1 to 3 days for males and 2 to 10 days for females. The average temperature of the 1-day stages was 81.5° F., and 70.5° F. for the 10 day stages.

The minimum time required for development from hatching to adult was 5 days for each sex at an average temperature of 80.5° F. The maximum time required from hatching to adult was 12 days for males at an average temperature of 73.4° F., and 20 days for females at an average temperature of 70.8° F.

The preoviposition period raged from 2 days at an average temperature of 82.8° F., to 6 days at an average temperature of 72.7° F.

The maximum life span for adult females was 14 days at an average temperature of 70.1° F. The maximum life span for adult males was 8 days at an average temperature of 66.7° F.

REFERENCES CITED

Cagle, L. R. 1949. Life history of the two-spotted spider mite. Va. Agr. Exp. Sta. Bull. **252**: 103–25.

Pritchard, A. E., and E. W. Baker. 1952. A guide to the spider mites of deciduous fruit trees. Hilgardia **21**(9): 253–87.

Tests with Furethrin Sprays and Aerosols Against House Flies, Mosquitoes, and Cockroaches[1]

J. H. FALES, O. F. BODENSTEIN, and P. G. PIQUETT, *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*

The synthesis of allethrin by Schechter *et al.* (1949, 1952) has opened the way to the preparation of other pyrethrin-like chemicals. One of the most promising is furethrin, which has been synthesized in Japan and in the United States (Matsui *et al.* 1952). Furethrin has a furfuryl group attached to the cyclopentenolone nucleus in place of the allyl group in allethrin.

Gersdorff & Mitlin (1952), in house fly tests by the turntable method, obtained relative toxicities for the original furethrin sample received from Japan, a sample prepared by chemists of the U. S. Bureau of Entomology and Plant Quarantine, a natural acid isomer of furethrin also prepared by Bureau chemists, and the pyrethrins. They found that furethrin was as toxic as the pyrethrins but only one-third as toxic as allethrin. The Japanese sample was only three-fourths as toxic as the purer sample from the Bureau. The natural acid isomer was twice as toxic as furethrin. All the furethrin samples gave high knockdown.

This paper reports tests in a Peet-Grady chamber with furethrin sprays and aerosols in comparison with those containing pyrethrins or allethrin against the house fly, *Musca domestica* L., the yellow-fever mosquito, *Aedes aegypti* (L.), the common malaria mosquito, *Anopheles quadrimaculatus* Say, the northern house mosquito, *Culex pipiens* L., and the American cockroach, *Periplaneta americana* (L.). Tests also were made against house flies and mosquitoes in which synergists were combined with furethrin. The furethrin sample used in this work was prepared by Bureau chemists.

HOUSE FLIES.—In the tests against house flies the Peet-Grady procedure was followed with the sprays, whereas the aerosols were delivered into the chamber from a laboratory dispenser equipped with a capillary nozzle 0.017 inch in diameter. The exposures were 10 minutes in the spray tests and 15 minutes in the tests with aerosols. In the sprays furethrin was compared with allethrin and the pyrethrins at concentrations of 1 and 2 mg. per milliliter of deodorized kerosene. Furethrin and the pyrethrins gave equal knockdowns at both concentrations. Allethrin gave a slightly reduced knockdown in 5 minutes at the lower concentration only, confirming previous reports by Fales *et al.* (1951) and by Moore (1950). In kill furethrin was considerably less effective than the pyrethrins at the low concentration, but at the high concentration it was nearly as toxic and allethrin was more effective then either furethrin or the pyrethrins.

An aerosol containing 1 per cent of furethrin plus 4 per cent of deodorized kerosene, 6 per cent of methylene chloride, and 89 per cent of *Freon-12* was compared with one containing 5 per cent of a 20-per cent pyrethrum extract with the same percentage of methylene chloride and *Freon-12*. In aerosols furethrin caused slightly less knockdown and kill than the pyrethrins.

The results with both prays and aerosols are given in table 1.

In the work with synergists 1 mg. of furethrin was combined with 4 mg. of MGK-264 per milliliter in one spray and with 4 mg. of piperonyl butoxide in another. The results as summarized in table 2 indicate synergism. The spray with piperonyl butoxide was more effective than the one with MGK-264 or with furethrin alone.

MOSQUITOES.—Only sprays were tested against mosquitoes. Ten-minute exposures were used except with *Aedes aegypti*, when the exposure was 5 minutes followed by 10 minutes of venting before the insects were col-

[1] Accepted for publication September 23, 1954.

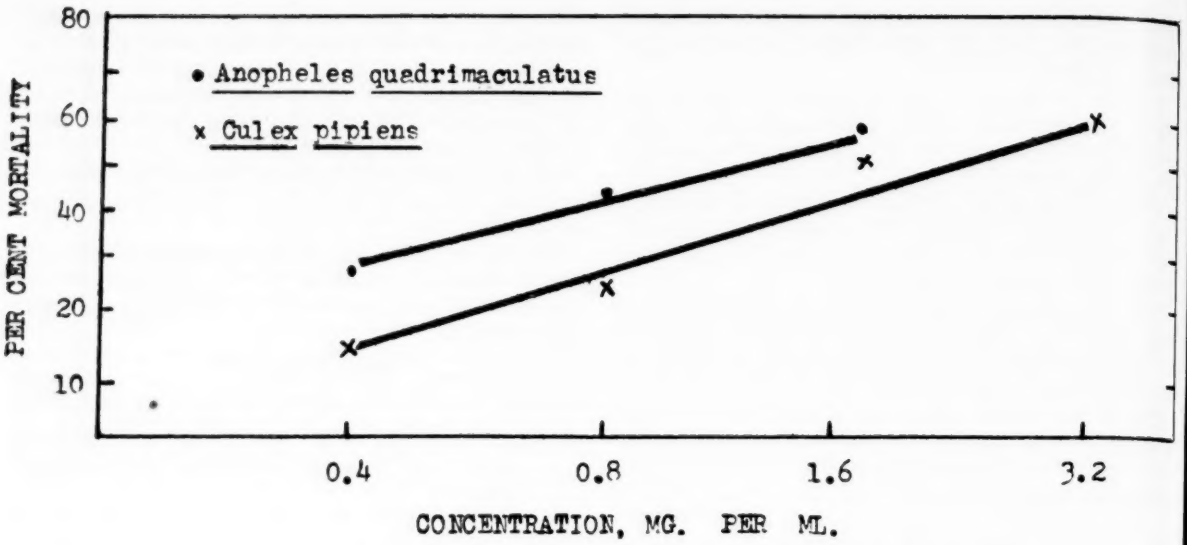


FIG. 1.—Mortalities of two species of mosquitoes in relation to concentration of furethrin sprays.

lected. The sprays were applied at the rate of 13.9 ml. per 1000 cubic feet. Since furethrin is closer to the pyrethrins than to allethrin in chemical structure, it was of interest to see whether the same relationship would be shown in its effectiveness against mosquitoes. In previous tests (Fales *et al.* 1952) *Aedes* required 8, *Anopheles* 2, and *Culex* approximately 5½ times as much allethrin as pyrethrins to obtain similar mortalities. Furethrin and allethrin were therefore tested against *Aedes aegypti* at 8 times the concentration of the pyrethrins. Furethrin was slightly less effective in mortality than allethrin; however, both materials at the increased concentrations caused mortalities in the range of those caused by the pyrethrins. High knockdown was obtained in 15 minutes with both concentrations of each material.

Table 1.—Comparative effectiveness against house flies of furethrin, allethrin, and the pyrethrins in sprays and furethrin and the pyrethrins in aerosols.

Insecticide	Number of Tests	Per Cent Knockdown in (Minutes) 5	10	15	Per Cent Kill in 1 Day
Sprays (55.56 ml. per 1000 cubic feet)					
Milligrams per Milliliter					
Furethrin	1	5	93	96	— 8
	2	9	95	98	— 28
Allethrin	1	5	85	95	— 30
	2	9	94	99	— 67
Pyrethrins	1	5	93	96	— 23
	2	9	95	98	— 35
Aerosols (4.63 grams per 1000 cubic feet)					
Per cent					
Furethrins	1	4	47	78	82 34
Pyrethrins	1	4	66	89	90 47

Eight times as much furethrin as pyrethrins was required to obtain nearly equal kill of *Anopheles* and about 4 times as much to give the same kill of *Culex*. These results are shown in table 3, and the concentration-mortality curves for female *Anopheles* and *Culex* only for furethrin in figure 1. High knockdown of both species was obtained in all tests except the one with 0.8 mg. of furethrin against *Anopheles*, which gave medium knockdown.

Sprays containing furethrin plus either MGK-264 or piperonyl butoxide were also tried against *Culex pipiens*. The results given in table 4 show that the spray containing piperonyl butoxide was again more effective in kill than the one with MGK-264 although it caused less knockdown.

COCKROACHES.—The aerosols tested against house flies were also compared against adult females of the American cockroach by the method described by Fales *et al.* (1951), using a dosage of 35 grams per 1000 cubic feet and a 30-minute exposure. The furethrin aerosol caused no knockdown or mortality, whereas the pyrethrum aerosol caused a knockdown of 55 per cent and kills of 0, 25, and 45 per cent in 1, 3, and 5 days, respectively. Furethrin is similar to allethrin when used against the American cockroach, since allethrin caused no kill as

Table 2.—Comparative effectiveness against house flies of sprays containing MGK-264 or piperonyl butoxide as synergists for furethrin.[a]

Insecticide (Milligrams per Milliliter)	Per Cent Knockdown in— 5 Minutes	10 Minutes	Per Cent Kill in 1 Day
Furethrin 1 plus—			
MGK-264 4	79	92	31
Piperonyl butoxide 4	84	93	86
Furethrin 1	76	89	14
2	91	96	38

[a] Average of five tests each.

Table 3.—Comparative effectiveness against mosquitoes of sprays containing furethrin, allethrin, or the pyrethrins.

Insecticide (Milligrams per Milliliter)		Number of Tests	Per Cent Kill in 1 Day	
			Males	Females
		Aedes aegypti		
Furethrin	0.264	6	68	33
	.528	8	84	66
Allethrin	.264	5	74	47
	.528	5	91	73
Pyrethrins	.033	9	63	39
	.066	6	80	53
		Anopheles quadrimaculatus		
Furethrin	0.4	2	74	26
	.8	7	77	41
	1.6	10	84	55
Pyrethrins	.2	10	87	59
		Culex pipiens		
Furethrin	0.4	7	38	14
	.8	6	62	21
	1.6	10	75	48
	3.2	5	90	60
Pyrethrins	.2	6	70	29

against 42 per cent for the pyrethrins by the same method (Fales *et al.* 1951).

CONCLUSIONS.—It is evident that furethrin is similar in action to allethrin. It causes slightly less kill of house flies than the pyrethrins or allethrin, but seems to be more effective than allethrin in knockdown. Even though furethrin is more closely related structurally to the pyrethrins than is allethrin, it is of the same order of effectiveness as allethrin against *Aedes* mosquitoes and the American cockroach. The mosquito tests showed the same relative susceptibility of the three species used as was found in previous studies.

Table 4.—Comparative effectiveness against *Culex pipiens* of sprays containing MGK-264 or piperonyl butoxide as synergists for furethrin.[a]

Insecticide (Milligrams per Milliliter)	Knockdown in 10 Minutes	Per Cent Kill in 1 Day	
		Males	Females
Furethrin 0.4 plus—			
MGK-264 1.6	High	50	32
Piperonyl butoxide 1.6	Medium	73	52
Furethrin 0.4	Medium	39	14
1.6	High	73	50

[a] Average of five tests each.

REFERENCES CITED

Fales, J. H., O. F. Bodenstein, and P. G. Piquett. 1951. A method for testing aerosols against cockroaches. U. S. Bur. Ent. and Plant Quar. **ET-297.**

Fales, J. H., O. F. Bodenstein, and P. G. Piquett. 1952. Effectiveness of allethrin and pyrethrins as sprays against three species of mosquitoes. Jour. Econ. Ent. **45**(4): 743–4.

Fales, J. H., R. H. Nelson, R. A. Fulton, and O. F. Bodenstein. 1951. Insecticidal effectiveness of sprays and aerosols containing allethrin. Jour. Econ. Ent. **44**(1): 23–8.

Gersdorff, W. A., and Norman Mitlin. 1952. Relative toxicity of furethrin, its natural acid isomer, and pyrethrins to house flies. Jour. Econ. Ent. **45**(5): 849–50.

Matsui, M., F. B. LaForge, N. Green, and M. S. Schechter. 1952. Furethrin. Jour. Amer. Chem. Soc. **74**(9): 2181–2.

Moore, J. B. 1950. Relative toxicity to insects of natural pyrethrins and synthetic allyl analog of cinerin I. Jour. Econ. Ent. **43**(2): 207–13.

Schechter, M. S., N. Green, and F. B. LaForge. 1949. Constituents of pyrethrum flowers. XXIII. Cinerolone and the synthesis of related cyclopentenolones. Jour. Amer. Chem. Soc. **71**(9): 3165–73.

Schechter, M. S., N. Green, and F. B. LaForge. 1952. Constituents of pyrethrum flowers. XXIV. Synthetic *dl-cis*-cinerolone and other cyclopentenolones. Jour. Amer. Chem. Soc. **74**(19): 4902–6.

Biology of the Red-Banded Leaf Roller in Southern Indiana[1]

S. A. SUMMERLAND[2] and D. W. HAMILTON, *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*

The red-banded leaf roller, *Argyrotaenia velutinana* (Wlkr.), attacks a wide variety of plants, including deciduous fruits, over much of the United States. However, it was seldom a serious pest in commercial orchards before fruit growers began to use DDT. Soon after DDT came into general use this leaf roller became more than normally abundant and caused serious damage in apple orchards in the Midwest and East. The area in and around Vincennes, Indiana, was one of the first in which it made such an appearance. In this area it first attracted attention in 1946 and has been a serious or potentially serious pest each year since then. Its presence afforded an opportunity to obtain information on its seasonal history and habits under southern Indiana conditions. This paper reports information on the biology of this pest obtained during the period 1950-1953.

The red-banded leaf roller overwinters as a pupa in leaves and debris on the ground under the trees on which it fed as a larva. Spring-brood adults generally begin to emerge during the latter part of March. The earliest date of their emergence observed is March 17 (1953) and the latest is April 4 (1951). Immediately after emerging adults remain near the ground, often hiding in the grass and debris. When disturbed they fly for a short distance and light on the ground. Later in the season, when it is warmer, they are more often observed flying about or

[1] Accepted for publication September 26, 1954.
[2] Retired January 31, 1954.

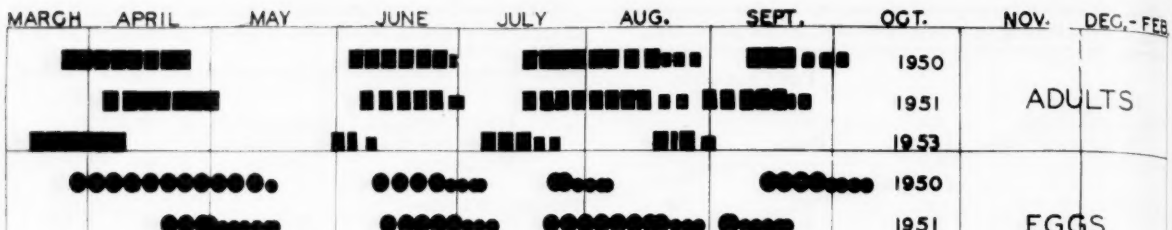


FIG. 1.—Red-banded leaf roller life history 1950, 1951 and 1953.

resting on the trunks and limbs of the trees, sometimes even near the tops of the trees.

The moths mate and begin to deposit eggs in masses within 3 days after emerging. Eggs of the first generation are usually deposited on the larger smooth-barked branches; however, any smooth surface is acceptable. Eggs of the later generations are generally deposited on leaves. In the insectary eggs are deposited on the glass jars used as cages. In orchards the first eggs of the year have been found between March 25 (1952) and April 4 (1951).

Hatching of first-generation eggs is bunched. All those in one mass usually hatch within a few hours, and most of those in all masses within a few days. In 1949, for example, 94 per cent of all first-generation eggs observed hatched within 3 days. Ordinarily hatching reaches a peak between April 20 and May 1 and is nearly complete by petal fall. Therefore, control measures applied at petal

Table 1.—Development of the Red-Banded Leaf Roller in the Insectary, Vincennes, Indiana, 1950–1953.

Generation and Stage	1950			1951			1953		
	Number of Individuals	Length of Stage (Days)		Number of Individuals	Length of Stage (Days)		Number of Individuals	Length of Stage (Days)	
		Range	Average		Range	Average		Range	Average
First									
Egg[a]	—	—	—	14	7–14	10.6	—	—	—
Larval	60	22–43	30.0	60	23–50	32.0	25	23–32	27.4
Pupal	68	7–12	8.9	30	6–12	9.9	25	7–9	8.0
Second									
Egg[a]	19	7–12	8.5	30	7–10	8.4	2	9–10	9.5
Larval	101	21–43	31.4	119	18–41	28.3	20	16–29	20.4
Pupal	107	7–11	8.9	86	6–17	8.2	19	6–9	7.7
Third									
Egg[a]	37	7–10	8.7	26	7–9	8.0	4	7–7	7.0
Larval[b]	9	26–49	34.0	12	20–32	24.5	24	18–27	21.2
Larval[c]	47	26–94	68.7	16	20–112	51.6	23	7–10	8.1
Pupal	5	10–13	11.0	9	6–11	8.6			
Fourth									
Egg[a]	7	11–13	11.9	6	11–13	11.7	3	7–7	7.0
Larval	—	—	—	8	67–82	76.2	3	73–83	79.0

[a] Numbers refer to egg masses.
[b] Those that complete their development to produce a partial fourth generation.
[c] Those that overwinter as pupae.

fall are especially effective. Egg masses sprayed with oil or deposited on oil-sprayed bark hatch irregularly over a period of 2 or 3 days, the center eggs being the first to hatch.

Some of the newly hatched first-generation larvae are carried by the wind from the egg masses on the trunk and branches of the trees to the leaves. They thus reach their feeding places without crawling over a sprayed surface.

At Vincennes there are three generations and a partial fourth generation annually. Actually, the third generation is not quite a complete one; some of the insects develop slowly and overwinter in the pupal stage on fallen leaves. Larvae developing late in the season feed almost entirely on fruit rather than leaves, causing severe damage to fruit just before harvest.

Red-banded leaf roller larvae withstand near-freezing temperatures and may continue to feed on and cause severe damage to apples in cold storage. They may also freeze without apparent injury. In 1951 the temperature dropped to 15° F. on November 1, when third- and fourth-generation larvae were nearing pupation. The larvae were frozen solid for 5 days, but most of them pupated when the weather moderated.

The time required for development of the several stages under insectary conditions is shown in table 1, and the seasonal history of the insect is shown in figure 1.

There are two sizes of symbols in figure 1. The larger symbols indicate that transformation to the given stage or the laying of eggs is under way, and the smaller symbols indicate that the stage can be found but no additional individuals are appearing.

Known parasites of the red-banded leaf roller are *Itoplectis conquistor* (Say) and *Coecygominus aequalis* (Prov.). The larvae are also attacked by a disease known as granulosis, first reported by Sibold (1950) as attacking this insect. In recent years this disease has caused substantial reductions in the numbers of larvae present in orchards throughout southern Indiana. Larvae affected are lighter in color than normal, turning almost white. They slowly diminish in size, become less active, and finally dry up and die.

REFERENCES CITED

Sibold, Nannie V. 1950. Granulosis of the Red-Banded Leaf Roller. Va. Jour. Sci. 1(n.s.) (3): 226.

A Search for Natural Enemies of Lecaniine Scale Insects in Northern Africa for Introduction into California[1]

ROBERT VAN DEN BOSCH, BLAIR R. BARTLETT, and STANLEY E. FLANDERS, *Department of Biological Control, University of California Citrus Experiment Station, Riverside*

Orchard and ornamental trees and shrubs in California are attacked by a number of lecaniine scales, the most important of which are the black scale, *Saissetia oleae* (Bern.); citricola scale, *Coccus pseudomagnoliarum* (Kuw.); soft (brown) scale, *Coccus hesperidum* L.; and the European fruit lecanium, *Lecanium corni* Bouché. The frosted scale, *Lecanium pruinosum* Coq.; Kuno scale, *Lecanium kunoensis* Kuw., and hemispherical scale, *Saissetia hemisphaerica* (Targ.), are of occasional local significance.

Of the pests named above, the black scale has been the one most vigorously attacked by the biological control method. This scale insect, once considered the most serious citrus pest in the state, has been reduced in abundance by imported natural enemies to an estimated one-fifth of its former population level. Thirty-eight species of entomophagous insects have been imported and released against this host; 15 of these have become permanently established. Six additional species, either native or accidentally introduced, also attack this scale in Calfifornia. Biological control by these species has been most successful in the mild coastal region of southern California, where black scale is double-brooded. In the interior areas, where the scale has only a single generation and climatic conditions are more extreme, biological control has been much less effective but is still of considerable importance.

The failure to attain fully satisfactory biological control of black scale in California has been due to two main factors: (1) the inability of most of the imported parasites to sustain their activity during unusually cold winter periods, and (2) the poor synchronization of certain parasites to a single-brooded host; their numbers being so seriously reduced during periods when favorable host stages are scarce that their effectiveness is curtailed.

An improvement in the biological control of black scale was thought possible through the importation of additional natural enemies from parts of Africa climatically similar to the inland areas of California. Exploration was carried out during the period January to May, 1953, by the senior author, with major activity centering on the high Hamasien plateau of Eritrea and in Morocco. A short period of time was also spent in Kenya Colony. Fifteen previously unobtained entomophagous insect species which attack black and other lecaniine scales were imported as a result of this exploration. The present paper discusses the conditions under which these species were obtained, certain aspects of their biologies, and their laboratory propagation and field release.

EXPLORATION.—Collecting activity in Eritrea extended over a period of about 2 months. The search for parasites of black scale was centered on the Hamasien plateau because of the known existence there of several

[1] Paper No. 833, University of California Citrus Experiment Station, Riverside, California. Accepted for publication September 27, 1954.

potentially valuable parasites and because of the similarity of the climate of this high tableland to that of parts of southern California. Eritrea had been previously visited by the Italian entomologist Filippo Silvestri (1914), who described a number of natural enemies of lecaniine scales from this area. Later, Harold Compere (1931), of the University of California, attempted to bring parasites from Eritrea to California. This attempt failed when parasitized stocks of black scale held at Suez under forced quarantine were lost because of extreme heat. The knowledge and experience gained by these men in their visits to Eritera were highly useful in the recent expedition.

On the Hamasien plateau and its eastern escarpment coccids were abundant. A number of lecaniine species were encountered, including at least four species of *Saissetia*. Extremely heavy infestations of soft scale and of hemispherical scale, invariably attended by ants, were commonly observed; but the true black scale, *Saissetia oleae* (Bern.), was found only in scattered colonies. A closely allied species, possibly *Saissetia persimile* (Newstead), was much more abundant. Black scale was not found on citrus in Eritrea, perhaps because commerical groves are situated in areas climatically unfavorable for its development. The bulk of the *S. oleae* material shipped to Riverside was taken from oleander (*Nerium oleander*) in the city of Asmara and from several heavily infested trees of *Croton macrostachys* in the village of Ghescinascim, about 15 miles north of Asmara.

A striking characteristic of the majority of parasites reared from the Eritrean collections was the lack of host specificity. This condition was more general among these parasites than among any comparable group ever before received in Riverside. However, among the lecaniine scales upon which these parasites have been tested, certain species tend to be favored; this indicates that specificity is developing among the closely allied parasites. As a matter of conjecture, it would seem that in Eritrea, where *Saissetia* apparently is indigenous, species of this genus and of closely allied genera support complexes of parasites which are in the process of evolution along with their hosts.

Exploration in Morocco was conducted in all three of the political subdivisions, French Morocco, Spanish Morocco, and the international zone, Tangier. Moroccan climatic conditions resemble those of California in that there is a coastal belt of mild climate and an interior region of relatively extreme conditions. The mixed growth stages of black scale found in the coastal area indicated the existence of two or more broods, while only mature adults were found at Fes in the interior, apparently a single-brooded area.

In Morocco the diversity of lecaniine scales, particularly of *Saissetia* spp., was not so great as in Eritrea. *Saissetia oleae* was encountered in light infestations on citrus at Rabat, French Morocco, but French entomologists stated that it is not a pest on this crop. Scattered heavy infestations attended by ants were encountered on oleander in Rabat and Tangier, and a rather extensive infestation was observed on olive in the single-brooded area at Fes.

Scale shipments were sent to Riverside by air mail in small light-weight containers sealed in cloth bags, with time in transit ranging from 4 to 7 days. Air-mail shipments from Eritrea totaled 60, and from Morocco, 15. Most of the shipments contained parasitized lecaniine scales; several contained miscellaneous material. Shipments of scale material were received in Riverside at the Quarantine Laboratory, where all known hyperparasites were screened out and all other species were tested for host preferences on a variety of lecaniine scales. The parasite and predator species obtained from this exploration are listed below, together with information on their biologies and field disposition.

PARASITES.—*Coccophagus eleaphilus* Silvestri was collected in both Eritrea and Morocco. This is a solitary internal parasite well adapted to black scale (*Saissetia oleae*) of 0.9 to 2.0 mm. in length. In the laboratory it also successfully attacks citricola scale and soft scale. Males of *C. eleaphilus* are internal parasites of females of their own species and of other species of *Coccophagus*. Both sexes darken the derm of the host scales. Approximately 35,000 females of this species have been reared on soft scale in the laboratory and released in the field. It has been recovered from black scale at several places in southern California.

Coccophagus eritreaensis Compere was collected in Eritera. This solitary internal parasite appears to be well adapted to a variety of lecaniine coccids but does not successfully attack black scale. In the laboratory it oviposits readily in soft scale, citricola scale, and brown apricot scale, attacking a wider range of host-scale sizes (range 1.0 to 4.0 mm.) than does *C. eleaphilus*. The males have habits similar to those of *C. eleaphilus*. The parasite meconia give the host scale a black appearance, but the derm itself is not darkened. Over 10,000 females have been colonized in California on various lecaniine hosts. This species has been recovered from soft scale in the field.

Coccophagus nigritus Compere was collected in Eritrea. This is a solitary internal parasite which attacks mature black scale. It cocoons and pupates in the living host but does not prevent the latter from ovipositing. Because of its long life cycle (30 to 37 days at 80° F.) and the late stage of scale which it attacks, this parasite appears to be of little potential value. Males are hyperparasitic, with habits similar to those described for *Coccophagus eritreaensis*. Only a few hundred *C. nigritus* were colonized, and this species has not been recovered from the field.

Coccophagus baldassarii Compere was collected in Eritrea. It is a solitary internal parasite with hyperparasitic males. This species proved to be poorly adapted to our California black scale, its preferred host probably being one of the closely associated species in its native land, *Saissetia oleae* being only a casual or incidental host as the result of population pressure. Very small liberations were made from the original insectary stocks, and no field recoveries were made.

Euxanthellus sp. was collected in Eritrea. It is a solitary internal parasite which has a 35-day life cycle at 80° F. (males are hyperparasitic). It attacked nearly mature soft scale in the laboratory but was not well adapted to any of our California lecaniine scales. Stocks were maintained

only with difficulty, and no colonizations were made because the host relationships of the species were not adequately determined.

Diversinervus elegans Silvestri was collected in Eritrea. This gregarious internal parasite attacks nearly mature stages of all the lecaniine species tested in the laboratory. It oviposits between the anal plates and into the host intestinal tract. Adults feed extensively on immature scale. Females develop in 20 or more days at 80° F. in the laboratory, but pupae may sometimes remain in the host for long periods before adult emergence. This adaptation is expected to be advantageous in carrying *D. elegans* over periods of host scarcity such as occur in single-brooded areas. Approximately 5,000 females of *D. elegans* have been released throughout California, and commercial insectaries are continuing to propagate and colonize this species in large numbers. Recoveries have been made at a number of release points from black, citricola, and soft scales.

Metaphycus sp. "Y" (undescribed) was collected in Eritera. This is a solitary internal parasite of black scale and citricola scale. It attacks small second-stage scale, and the life cycle within the host is completed in less than 13 days at 80° F. Its rapid development and ability to attack newly settled scale (as small as 0.5 mm.) should enable it to pass through a number of generations even in single-brooded areas. Approximately 10,000 females have been released by the Department of Biological Control of this station, and commercial insectaries have produced and colonized more than 100,000. *Metaphycus* sp. "Y" has been recovered from black scale at several places.

Metaphycus praevidens (Silv.) was collected in Eritrea. It is a solitary internal parasite similar in appearance to *Metaphycus* "Y." It attacks slightly larger scale than does the latter, and this has permitted simultaneous rearing of the two species, which are nearly indistinguishable. Approximately 10,000 females have been colonized through the joint activities of the Department of Biological Control and commerical insectaries. This species has not been recovered from the field.

Metaphycus flavus (How.) was collected in Morocco. It is an internal parasite, either solitary or gregarious in habit. It has been reared in the laboratory on several lecaniine hosts. Its black scale attack appears to be limited to early second-stage scale, and development is as a solitary parasite; whereas its attack on soft scale includes all stages from early second instar to mature scale. Over 35,000 adult parasites have been liberated. *M. flavus* has been recovered from citricola and black scale in the majority of places where it was colonized. It is abundant in these places and appears to be permanently established.

A *Metaphycus* sp. reared from *Saissetia* was collected in Eritrea but was not obtained in large enough numbers to permit propagation and release. This was also the case with *Metaphycus hemilecanii* Compere, collected in Kenya.

COCCINELLID PREDATORS.—In addition to the parasites discussed above, four coccinellid species were obtained, three from Eritrea and the fourth from Morocco. These species have proved to be especially interesting in the laboratory because of the ability of each to feed and develop on diverse hosts. Approximately 1000 or more of each of these beetles have been liberated against black scale, and propagation is being continued by commerical insectaries in an attempt to effect permanent establishment.

A *Chilocorus* sp. (near *distigma* Klug) was associated with both lecaniine and diaspine scales in Eritrea. In the laboratory this species reproduces on both armored and unarmored scales, and it has been liberated in areas where both types of host occur together.

A *Hyperaspis* sp. (new) was collected in Eritrea. This lady beetle feeds and reproduces satisfactorily on both unarmored scales and mealybugs.

A coccinellid of a new genus (near *Platynaspis*) was collected in Eritrea. In the laboratory it has fed voraciously on all the lecaniine and diaspine scales so far tested, as well as on mealybugs. If this beetle becomes established, its polyphagous habits should be highly advantageous in the coastal citrus-growing areas where mealybugs and scale insects occur together.

Exochomus floralis (Motsch.) was found in abundance at two places near Fes, French Morocco, in association with black scale. In the laboratory it also feeds and reproduces on diaspine scales. Since *E. floralis* was collected in the single-brooded black scale area of Morocco, there is basis for hope that it can develop to a position of importance in similar areas in California.

None of the coccinellids discussed above have been recovered from the field. However, since insectary propagation of the beetles has been slow, only limited releases have been made, and considerably more time must pass before they have had a reasonable chance to become established.

SUMMARY.—Twenty-one species of primary parasites and of predators are now definitely known to be established on black scale in California. These natural enemies have greatly reduced the black scale problem, but occasionally after cold winters or in single-brooded scale areas economic control is not maintained. To improve on existing biological control, additional beneficial insects were sought in northern Africa, in Eritrea, and Morocco, in 1953. Eight of the eleven species of primary parasites, as well as four species of predators, obtained during this search have been reared in the insectary and released in the field. Five of the parasite species have been recovered so far. The conditions under which these natural enemies were collected and certain aspects of their biologies are described.

REFERENCES CITED

Compere, Harold. 1931. A discussion of the parasites of *Saissetia oleae* (Bern.) collected in Eritrea. Univ. Calif. Pubs. Ent. 5(12): 247–55.

Silvestri, F. 1914. Contributo alla conoscenza degli insetti dell' olivo dell' Eritrea e dell' Africa medridionale. Portici R. Scuola Super. di Agr. Lab. Zool. Gen e Agr. Bol. 9: 240–334.

Evidence for Green Peach Aphid Resistance to Organo-Phosphorous Insecticides[1]

EDWARD W. ANTHON[2]

Following the early classic work of Melander (1914) on the resistance of San Jose scale to lime-sulfur in Washington, there have been numerous similar accounts involving a wide range of insects and insecticides (Babers & Pratt 1951). To the writer's knowledge, however, no authentic case of insecticide resistance in aphids has been presented except that of Boyce's (1928) when, by artificial selection, he produced strains of the cotton aphid, *Aphis gossypii* Glov., which showed a slight resistance to hydrocyanic acid fumigation. The information herein reported is evidence that the green peach aphid, *Myzus persicae* (Sulz.), on peaches may have developed resistance to several organo-phosphorous insecticides under field conditions in north central Washington.

Malathion, parathion, or TEPP have been used effectively against this aphid in the past on peaches. However, in early April of 1953, experimental trials of malathion showed poor performance where high populations of the aphid were encountered. In late April complaints from various growers in the Trinidad and Rock Island areas showed that control was not being obtained with parathion or combinations of parathion and DDT. One grower applied as much as 4 pounds of 25 per cent parathion wettable powder per 100 gallons of water and failed to get satisfactory control of the aphid.

Observations and aphid counts confirmed this in several northcentral Washington peach orchards. The orchards examined were managed by competent and experienced fieldmen who sprayed thoroughly and who, in the past, have obtained excellent control of this pest with these materials. In view of these circumstances a number of sprays were applied to prove or disprove these reports. The first was made April 24 to five young peach trees per plot. Counts were obtained by examining 25 aphid-infested blossoms and 50 infested leaves per plot. In this preliminary work only two materials were used—liquid formulations of Systox 42.4 per cent, and malathion, 57 per cent. The results are shown in table 1.

Soon after, several growers were experiencing the same difficulty in the Trinidad area. A grower's orchard which had a severe infestation of these aphids was selected for additional investigations in which a complete series of organo-phosphorous insecticides, including parathion, malathion, TEPP, Metacide and Systox, plus two non-phosphorous materials, lindane and nicotine, were used. These additional treatments were made to eliminate any possibility of poor materials or inadequate spray applications as a reason for poor control.

Table 1.—Control of aphids on peaches with malathion and Systox, Rock Island, Washington. 1953.

Insecticide per 100 Gallons Water	Pre-treatment Counts 4-23-53	Post-treatment Counts 4-25-53	Per Cent Aphid Mortality
Malathion, 1½ pts.	425	103	75.8
Systox, ½ pt.	437	3	99.3
Untreated	403	540	none

Table 2.—Mortality of green peach aphid following several sprays, Trinidad, Washington. 1953.

Materials[a] Used per 100 Gallons of Water	Pre-treatment Counts 5-4-53	Post-treatment Counts 5-7-53	Per Cent Change in Aphid Population
Parathion W.P. (25%), ½ lb.	2448	2578	+ 5.3
Parathion Emul. (25%), ½ pt.	2191	1852	−15.5
Malathion Emul. (57%), 1½ pts.	2471	1645	−33.4
Lindane (25%), 1 lb.	2068	525	−74.6
Metacide (33%), ½ pt.	2501	1675	−33.0
TEPP (20%), ½ pt.	2708	38	−98.6
Nicotine (40%), 1 pt.	2788	56	−98.0
Systox[b] (42.4%), ¼ pt.	141	3	−97.9

[a] Parathion and malathion, supplied by American Cyanamid Company. Systox supplied by Chemagro Corporation.
[b] Aphid counts made 5-8-53 on Systox-treated tree showed 100 per cent mortality. Only one tree treated with Systox; other treatments each applied to a block of five trees.

The insecticides were analyzed for purity to determine whether or not there was any breakdown of the insecticides which would account for the poor control. Parathion showed a slight loss of grade, but this is believed to be of little significance.

The sprays were applied May 5, 1953, with a portable sprayer, using a conventional hand gun, to blocks of five peach trees per treatment. Aphid counts were made by examining 20 infested leaves per tree. Results are given in table 2.

An additional trial on five trees was then sprayed with 2 pounds 25 per cent parathion, wettable powder. The results of this spray showed only 12 per cent mortality of green peach aphids at this high dosage.

Since TEPP was economical and showed some promise against this pest, it was recommended and used by three growers in the same area at ½ pint per 100 gallons of water. One grower obtained fair control, but the other two claimed no benefit. Additional applications of TEPP, malathion and parathion were made throughout May, but gave very little control.

When the field experiments had been completed, aphids were taken from field trees which had been sprayed several times with phosphorous insecticides and brought into the greenhouse where they were reared on small Lovell seedlings. After they became established, they were sprayed under laboratory conditions with 1 pound of 25 per cent parathion wettable powder with excellent control.

Mr. B. J. Landis and his associates, U. S. Department

[1] Scientific Paper No. 1317, Washington Agricultural Experiment Stations, Pullman. Project No. 1090. Accepted for publication September 27, 1954.
[2] Associate Entomologist, Tree Fruit Experiment Station, Wenatchee, Washington.

of Agriculture, Entomology Research Branch, experienced unusual difficulty in controlling the green peach aphid on potatoes in 1952 in the lower Yakima Valley of Washington and numerous failures were reported from potato growers in the area. In the fall of 1952 aphids were collected from a field of potatoes at Yakima where applications of DDT, TEPP, parathion, and malathion had been made, chiefly with aircraft, without satisfactory control. These aphids were then reared on Lovell peach seedlings in the greenhouse at Wenatchee and sprayed with various insecticides. Parathion, malathion, Systox and lindane all gave excellent control under the laboratory conditions.

The differences in susceptibility of the green peach aphid to various organo-phosphorous insecticides in the field and the laboratory are not well understood, but the laboratory trials were probably conducted under more ideal conditions and may have accounted for the difference in mortality. However, it has been established that the green peach aphid is becoming more difficult to kill under field conditions.

SUMMARY.—Green peach aphid, *Myzus persicae* (Sulz.) has become difficult to control with various organophosphorous insecticides in several peach orchard areas in northcentral Washington. Preliminary tests indicate that Systox or nicotine will give commercial control of this insect at the present time.

REFERENCES CITED

Babers, Frank H., and John J. Pratt. 1951. Development of insect resistance to insecticides II a critical review of the literature up to 1951. U.S.D.A. B.E.P.Q.E. **E-818.**

Boyce, A. M. 1928. Studies on the resistance of certain insects to hydrocyanic acid. Jour. Econ. Ent. **21:** 715–20.

Melander, A. L. 1914. Can insects become resistant to sprays? Jour. Econ. Ent. **7:** 167–72.

Relation of Water Loss to the Hatching of Eggs from Detached Oöthecae of *Blattella germanica* (L.)[1]

LOUIS M. ROTH and EDWIN R. WILLIS, *Pioneering Research Laboratories, U. S. Army Quartermaster Research and Development Center, Natick, Massachusetts*

The females of the German cockroach, *Blattella germanica* (L.), carry their oöthecae externally until or shortly before the eggs hatch. According to Ross (1929) when 9-day old or older oöthecae were removed from females, the eggs could hatch if the egg cases were kept under cool humid conditions; however, when oöthecae younger than 9 days were removed, the eggs failed to hatch under any conditions. Woodruff (1938) noticed that a green band appeared in the alimentary tract (which can be seen through the wall of the oötheca) of embryos of *B. germanica*, usually 3 days before hatching; he claimed that the eggs in oöthecae removed from females prior to the appearance of this band failed to hatch. Parker & Campbell (1940) found that the green band may first be observed 6 to 7 days before the eggs hatch (17 to 28 days at 76° to 83° F.). However, they found that some eggs hatched from oöthecae which were removed from females long before the appearance of the green band in the embryos. Some of the eggs in one oötheca hatched 24 days after being detached from the female which would indicate that this oötheca was fairly young at the time of its removal. In this paper we present some data which may explain the above discrepancies in hatching of eggs from detached oöthecae.

The cockroaches were reared on Purina dog chow checkers. Females that were forming oöthecae were isolated every 24 hours and kept, until used, at 27° to 29° C. with food and water. The insects were anesthetized with CO_2 when the oöthecae were manually removed. The egg cases were weighed on a torsion balance that was sensitive to 0.05 mg. Oöthecae were air-oven dried at about 80° C. to constant weight.

In table 1 and figure 1A and 1B is shown the effect of relative humidity on the hatching of eggs from detached oöthecae of *B. germanica*. The eggs in oöthecae kept at a low humidity of 30 per cent to 50 per cent did not hatch unless they had almost completed their development before being detached; at the low humidity the percent-

Table 1.—Effect of relative humidity on hatching of eggs from manually detached oöthecae of *Blattella germanica*.

Age (Days) of Oöthecae When Detached	Oöthecae Kept at 27°–29° C. and: 30%–50% R. H. Number Used	30%–50% R. H. Number from Which Some Eggs Hatched	90% R. H. Number Used	90% R. H. Number from Which Some Eggs Hatched
1	20	1	34	16
2	20	0	29	1
3	22	0	31	0
4	21	0	47	1
5	20	0	32	1
6	27	0	23	1
7	40	0	28	10
8	35	1	32	22
9	17	0	20	17
10	20	2	27	24
11	29	3	17	16
12	69	3	33	26
13	40	4	22	20
14	50	9	22	22
15	61	9	10	10
16	34	31		
Total	525	63	407	187

Accepted for publication September 27, 1954.

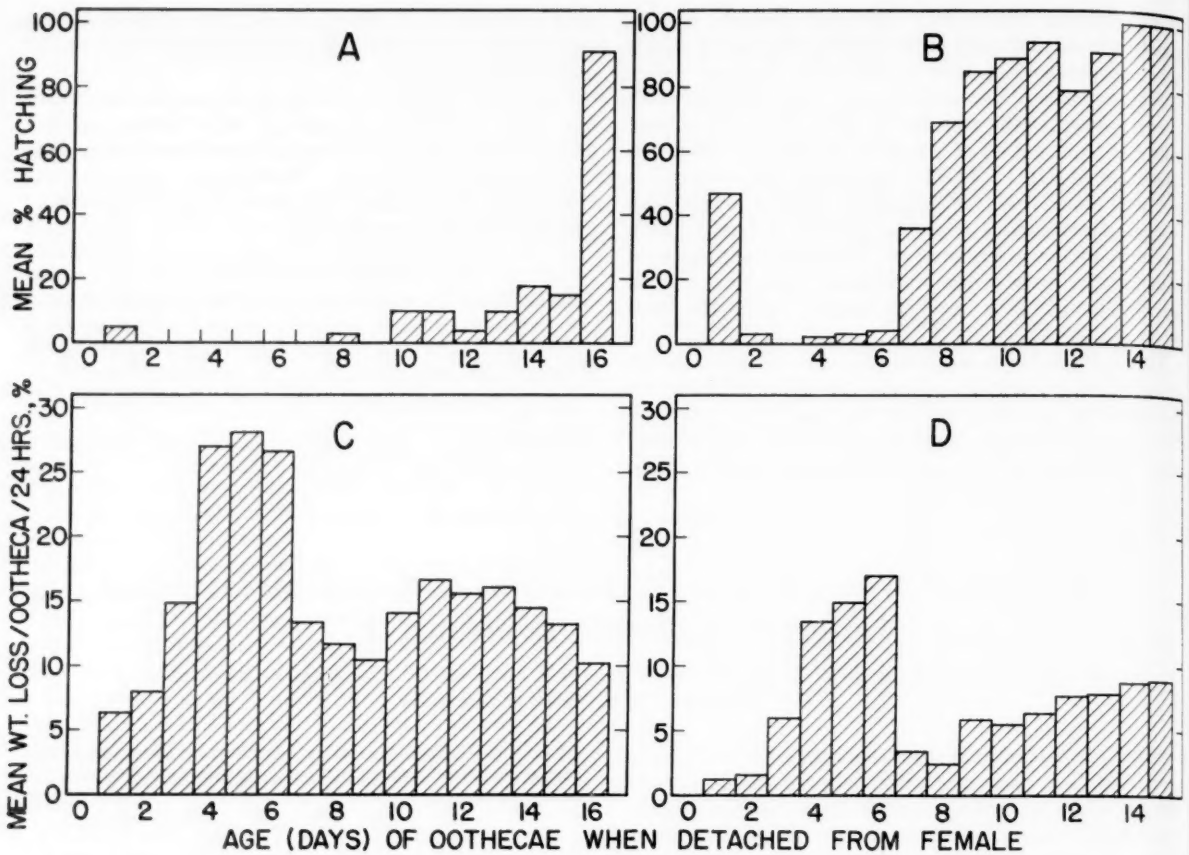


FIG. 1.—Effect of relative humidity on weight loss and hatching of eggs in manually detached oöthecae of *Blattella germanica*. A–B. Mean per cent hatching refers to the per cent of the oöthecae used from which eggs hatched. A = Oöthecae kept at 30% to 50% relative humidity. B = Cöthecae kept at 90% relative humidity. (Data from table 1.) C–D. Mean weight loss, over a 24 hour period, of manually detached oöthecae. C = Oöthecae kept at 30% relative humidity; from 6 to 29 Cöthecae were used for each age group (total of 373 egg cases). D = Oöthecae kept at 90% relative humidity; from 6 to 24 oöthecae were used for each age group (total of 171 egg cases).

age hatch was high only when the egg cases were detached from the females one day prior to hatching. When oöthecae were kept at 90 per cent R. H., a high percentage hatch was obtained only if the oöthecae were 1-day or 7 to 14 days old when removed from the females; even at this high humidity there was little or no hatch from oöthecae that were 2 to 6 days old when detached. The fact that detached 1-day old eggs will develop and hatch at 90 per cent R. H. shows that the recently-formed eggs of the German cockroach contain enough water to complete development without the additional water which normally is picked up from the female during embryonic development; even at the high humidity water is not taken up by detached eggs, but both weight (Figs. 1D, 3) and water (as indicated by the marked drop in weight) are continuously lost.

Table 2.—Effect of relative humidity on development and hatching of eggs from manually detached oöthecae of *Blattella germanica*.

Age (Days) of Oöthecae When Detached	Mean No. Eggs per Oötheca	Per Cent Eggs per Oötheca Which:		Number of Oöthecae Used[b]
		Developed	Hatched[a]	
Control[c]	30.4	98.5	99.9	26
	Oöthecae kept at 30% to 50% R. H.			
1, 8, 10–14	36.1	95.2	69.6	23
15–16	34.4	94.1	88.4	40
	Oöthecae kept at 90% R. H.			
1–2, 4–8	32.8	94.8	83.6	52
9–15	32.0	98.3	93.3	135

[a] Based only on eggs which developed.
[b] Some eggs hatched from all oöthecae used.
[c] Oöthecae left on females until eggs hatched.

Eggs did not hatch from detached, 2- to 4-day old oöthecae kept at a low humidity; few of the eggs developed into recognizable embryos, and those that did were situated at the sclerotized posterior end of the oötheca. When 5-day old or older oöthecae were removed from the females, most of the eggs developed; those that did not develop were located at the soft anterior end of the oötheca. These results are attributed to the difference in permeability of the two ends of the oötheca; water is lost more rapidly from the anterior end of detached oöthecae (Roth & Willis 1955). Even though hatching did not oc-

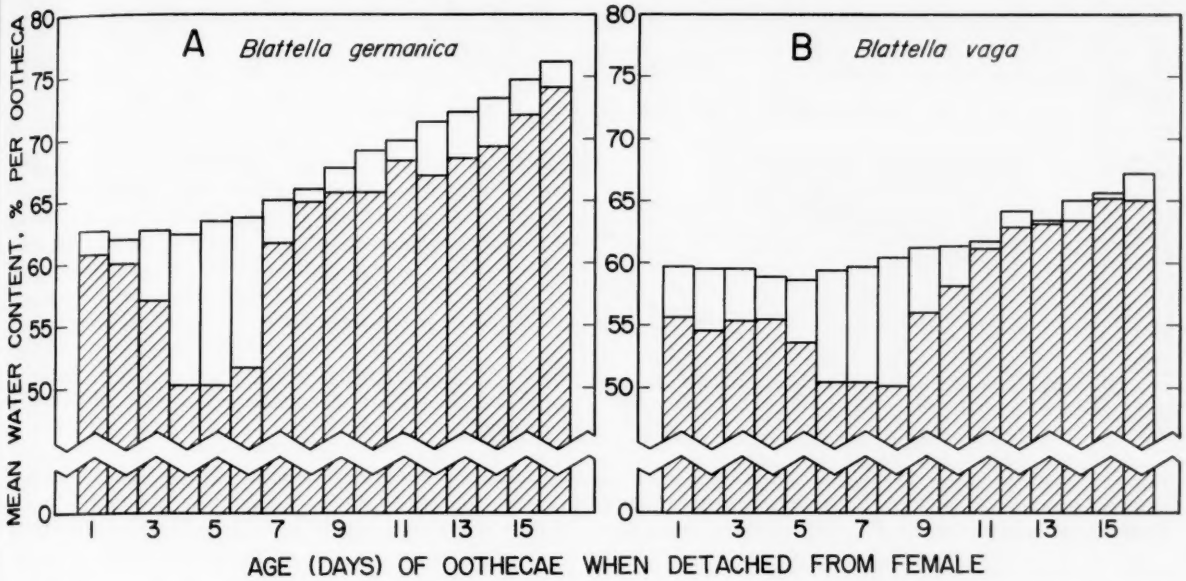


FIG. 2.—Water content of the oöthecae of *Blattella*. Open bars = Normal water content; from 20 to 30 oöthecae (total of 385) of each age group of *B. germanica*, and from 10 to 15 oöthecae (total of 220) of each age group of *B. vaga*. Hatched bars = Water content after 24 hours at about 30 per cent relative humidity; the same oöthecae of *B. germanica* used in figure 1C were used here and from 9 to 24 oöthecae (total of 227) of *B. vaga*.

cur, many eggs developed to mature embryos at 90 per cent R. H. regardless of the age at which the oötheca was detached. Of those oöthecae from which eggs hatched, the percentage of eggs which developed, per oötheca, was high, regardless of the age when detached or the humidity at which they were kept; however the percentage of eggs, per oötheca, which hatched was smaller at the low humidity, and at both high and low humidities the younger groups of detached eggs had a smaller per cent hatch than the older groups (Table 2).

It is evident that even at the high humidity there is a critical period, from the second to the sixth day, during which most of the eggs will not hatch if the oöthecae are detached from the females at that time, We kept 2- to 5-day old oöthecae on filter paper moistened with physiological saline solution, as recommended by Parker & Campbell (1940), and found that the eggs in 40 per cent to 54 per cent of the oöthecae hatched (Table 3); the

Table 3.—Hatching of eggs of *Blattella germanica* from oöthecae kept in contact with physiological saline solution.

Age (Days) of Oöthecae When Detached	Number Used	Hatched		Age (Days) When Removed from Saline Solution and Kept at 90% R. H.
		Number	Per Cent	
2	20	8	40	13
3	7	3	43	14
4	24	13	54	15
5	21	10	48	16

percentage hatch would probably have been higher were it not for bacterial and fungal growth which was uncontrolled. Evidently the failure of eggs to hatch from oöthecae removed from females during this critical period is not due to injury to the eggs themselves, although the possibility that the oöthecae have been damaged in some way still remains; however, many 1-day old oöthecae were successfully removed without apparent injury.

The weight loss by oöthecae of different ages, over a 24-hour period, is shown in figure 1C and 1D. At about 30 per cent R. H. (Fig. 1C) the least amount of weight lost was from eggs in oöthecae that were 1-day old when removed from the females. The greatest loss occurred from oöthecae detached when they were 4 to 6 days old. At 90 per cent R. H. the amount of weight lost was less than that found in oöthecae kept at the lower humidity, but here again the loss varied with the age of the oötheca at the time of removal from the female; again 1-day old oöthecae lost the least weight and the 4- to 6-day old oöthecae lost the most. At 90 per cent R. H. the critical period during which little hatching occurred corresponds closely with the period during which the greatest weight was lost (cf., Figs. 1B and 1D). The greater weight loss at 30 per cent R. H. during the critical period was due to the greater water loss (Fig. 2A); this is undoubtedly true at 90 per cent R. H. although water determinations were not made of oöthecae kept at this humidity. The oöthecae of *Blattella vaga* Heb. lose weight and water in a similar manner; but the critical period during which the most weight and water was lost was 6 to 8 days in *B. vaga* (Fig. 2B) compared to 4 to 6 days in *B. germanica*.

It seems reasonable to conclude that the rate of water loss is determined by the age of the eggs at the time the oöthecae are removed from the females. The difference in

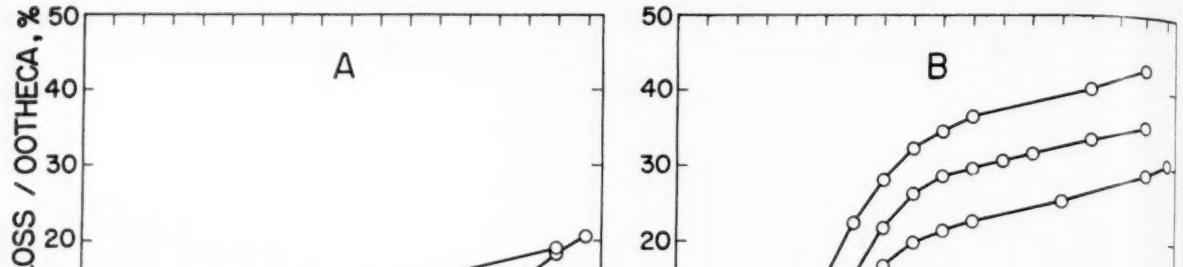


FIG. 3.—*Blatella germanica*. Effect of age, at time of removal from female, on rate of weight loss of manually detached oöthecae kept at 90 per cent relative humidity. Each curve starts (black semicircle) at the age the oöthecae were when removed from the females. From 6 to 15 oöthecae (total of 77) were used for each age group. In figure A some eggs hatched from each of the oöthecae whereas in B none of the eggs hatched.

time of occurrence of the critical period when the greatest amounts of water are lost can be correlated with developmental time of the eggs of *Blattella;* the eggs of *B. germanica* hatched in 17 days while those of *B. vaga* in 20 days. The weight changes in detached German cockroach oöthecae of different ages kept at 90 per cent R. H. were followed periodically from the time of their removal from the females until hatching (Fig. 3). It is interesting to note that although the rate of weight loss from 1-day old oöthecae increased somewhat when the eggs became 4 to 6 days old, the increase was not large enough to prevent the eggs from completing their development and hatching. If the high rate of water loss of 3- to 6-day old eggs were due to a particular stage of development of the egg (e.g., certain membrane changes such as are found in grasshopper eggs), one would expect a sudden increase in water loss when the eggs reached this so-called critical period in age. Perhaps the oötheca may be damaged in some way when removed at 2 to 6 days of age so that water is lost more rapidly.

The proportion of water in the oötheca and eggs of *B. germanica* is initially about 62 per cent by weight. In oöthecae carried by females this remains fairly constant for about 4 days and then gradually increases to about 75 per cent by the time of hatching, as dry weight is lost and water is absorbed from the female (Fig. 2A, open bars; Roth & Willis 1955). Whether or not the eggs in detached oöthecae will survive and hatch will depend on the rate of water loss and the amount of water present at the time of removal from the female. When kept at a high humidity some 1-day old eggs lose water so slowly (Fig. 3A) that they complete their development and hatch. Eggs in oöthecae detached when 2 to 6 days old lose water too rapidly (Fig. 3B) to hatch. Seven-day old or older eggs have begun to increase in water content; thus even though the rate of water loss in older eggs may be the same or greater than the 2- or 3-day old eggs (cf., Figs. 3A and 3B), hatching can take place in the older eggs because they have more water and have nearly completed their development. Unfortunately, practically nothing is known of the physical or chemical properties of cockroach egg membranes which control water loss; this lack of information makes it difficult to interpret the results of this investigation (cf. Salt 1952).

SUMMARY.—When kept at a high humidity, a large percentage of eggs in detached oöthecae of *Blattella germanica* hatch if the egg cases are 1 or 7 or more days old when removed from the females. When kept at a low humidity there is little or no hatch from eggs in detached oöthecae except in egg cases removed about 1 day prior to hatching. Hatching of eggs in detached oöthecae depends on the rate of water loss, the amount of water present in the eggs at the time the oötheca is removed from the female, and the amount of time remaining to complete development. The rate of water loss varies with the age of the oötheca at the time of detachment. The slowest rate of loss occurs in oöthecae which are 1-day old when detached, and the greatest rate of loss occurs in eggs which are 4 to 6 days old at the time of removal from the female.

REFERENCES CITED

Parker, B. M., and F. L. Campbell. 1940. Relative susceptibility of the ootheca and adult female of the German cockroach to liquid household insecticides. Jour. Econ. Ent. **33**(4): 610–14.

Ross, H. H. 1929. The life history of the German cockroach. Trans. Ill. State Acad. Sci. **21**: 84–93.

Roth, L. M., and E. R. Willis. 1955. Water relations of cockroach oöthecae. Jour. Econ. Ent. **48**: 30–6.

Salt, R. W. 1952. Some aspects of moisture absorption and loss in eggs of *Melanoplus bivittatus* (Say). Canadian Jour. Zool. **30**(1): 55–82.

Woodruff, L. C. 1938. Observations on roach reproduction. Jour. Kans. Ent. Soc. **11**(3): 94–6.

Zonal Dispersion of Chemicals in Soil Following Several Tillage Methods[1]

W. H. Lange, Jr. and E. C. Carlson, *University of California, Davis*

In connection with the practical application of soil chemicals for general broadcast treatment for the control of certain subterranean insects the determination of the best method of incorporating the chemicals in the soil is very important. In experimental work it is often necessary to ascertain the zonal dispersion of the chemical in the soil and to know whether a chemical remains within the plot boundaries following mixing in the soil.

Morrison & Crowell (1952) used iron filings to determine the distribution of chemicals in the soil following rotary tillage and double discing. They found that seed bed preparation, method of tillage, and soil type influenced thoroughness of distribution. These authors also found contamination of plots by tillage equipment and had to modify their experimental plots accordingly. Hulbert & Menzel (1953) used radioactive phosphorus and sorghum grains to study the relationship of tillage implements and soil conditioner placement. They found it necessary, for example, to use two operations with a rotary tiller to mix conditioners equally in the soil to a 6-inch depth.

Materials and Methods.—Four different chemicals were applied to replicated plots on April 10, 1951, using a Yolo clay loam soil at Davis, California. The chemicals and actual amounts used per acre were as follows: lindane 2 pounds; aldrin 10 pounds; dieldrin 5 pounds; DDT 20 pounds; and untreated. Three randomized blocks, 50 feet wide by 25 feet long, or 1250 sq. ft., were sprayed with each chemical using wettable powders. Compressed air hand sprayers were utilized and 3 quarts of spray were applied per plot. An untreated buffer strip of 10 feet was left between each plot, and 20 feet of untreated buffer was left between each replication, in addition to the untreated checks. Each of the plots was subdivided lengthwise into three plots, 10 feet wide, according to type of tillage treatment as follows: A, harrowed each way with a spike tooth to a depth of 1.75 to 2.25 inches; B, rotary tilled once to a depth of 4.75 to 5.0 inches; and C, disced 6 times in two directions to an average depth of 5.0 inches (range 4.5 to 5.5 inches). Each tilled sub-plot was 10 feet wide by 25 feet long. The longitudinal placement of plots made it possible to till all of the plots with a similar method in the longitudinal direction. In the cross direction, contamination was avoided by using similar treatments and a buffer of 10 feet between the three sub-plots.

The distribution of the chemicals in the soil was determined by a laboratory bioassay method using the Pacific Coast wireworm, *Limonius canus* Lec., and, in the case of aldrin and dieldrin a colorimetric (Danish & Lidov 1950) and a bioassay method on houseflies, respectively. Aldrin treated soils were occasionally analyzed by bioassay, using house flies.

Soil was sampled at two time intervals, 7 days, and 148 days, following treatment. A soil sampling tube made of EMT (electrical manufacturers tubing) tubing, of cadmium plated steel of 1.5 inches diameter was used in taking the soil samples (Fig. 1). The soil tube had a high carbon steel tip or tool steel, of $1\frac{5}{16}$ inches inside diameter for the first $\frac{1}{2}$ inch then extending to 1.5 inches.

Fig. 1.—Soil Sampler used in taking samples.

A total of 200 cores of soil were taken for each treatment at two depths, surface to 2.5 inches, and 2.5 to 5.0 inches. The soil was lightly sprinkled prior to taking the samples so it would be moist enough to obtain a good core. For the wireworm bioassay tests, the soil was selected at random from the initial sample and screened through a 14-mesh screen and used to fill 10 4-ounce salve cans to three-quarters capacity. One-fifth teaspoonful of cracked corn was placed in each can and buried in the soil. Distilled water was added to bring the moisture up to 10–12 per cent. One wireworm was introduced into each can, using 10 replications for each chemical, depth, and tillage method. Cans were held at 58–60° F. and examined at 2-week intervals, up to 6 weeks, for mortality. The total

[1] Accepted for publication September 27, 1954. Part of the cost of the illustrations paid by the authors.

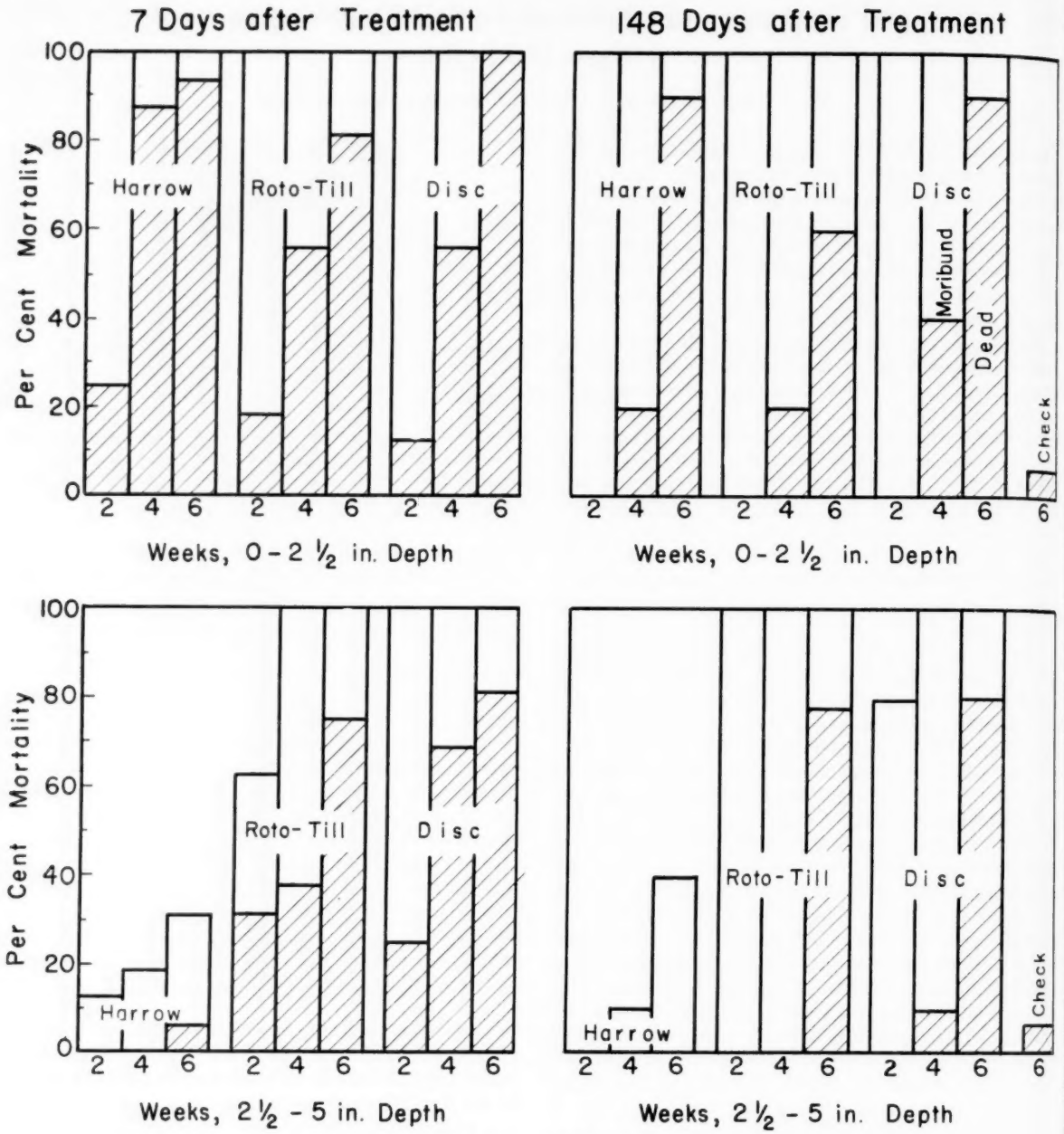


FIG. 2.—Wireworm mortality obtained from soil treated with 10 pounds of actual aldrin per acre in relation to method of incorporation and persistence after treatment.

mortality was determined in relation to those moribund and dead within the 6-week period. It was found that worms classed as moribund do not usually recover even if kept under observation for extended periods of time.

RESULTS.—The results of the bioassay tests using the wireworm, *Limonius canus* Lec., are portrayed graphically in figures 2–6.

Aldrin-treated soil at 7 days following treatment in the 0 to 2.5 inch zone affected wireworms with all three methods of tillage, although harrowing gave a more rapid initial kill. At the 2.5 to 5 inch zone harrowing gave poor kill as shown in figure 2, but rotary tillage and discing gave similar effects. That this difference is due to the poor distribution of aldrin by harrowing is shown in table 1, which indicates that at least 10 times as much aldrin was found in the upper 2.5 inches of soil. At 148 days similar effects on wireworms were obtained by the three tillage methods at the top level, although the velocity of kill was more rapid with harrowing. At the 2.5 to 5-inch level the ineffective distribution with harrowing is evidenced, but rotary tillage and discing gave similar effects.

Lindane at 2 pounds of actual chemical per acre gave a very rapid and effective kill at the 7 day sampling date in the top zone (Fig. 3). Rotary tillage and discing gave

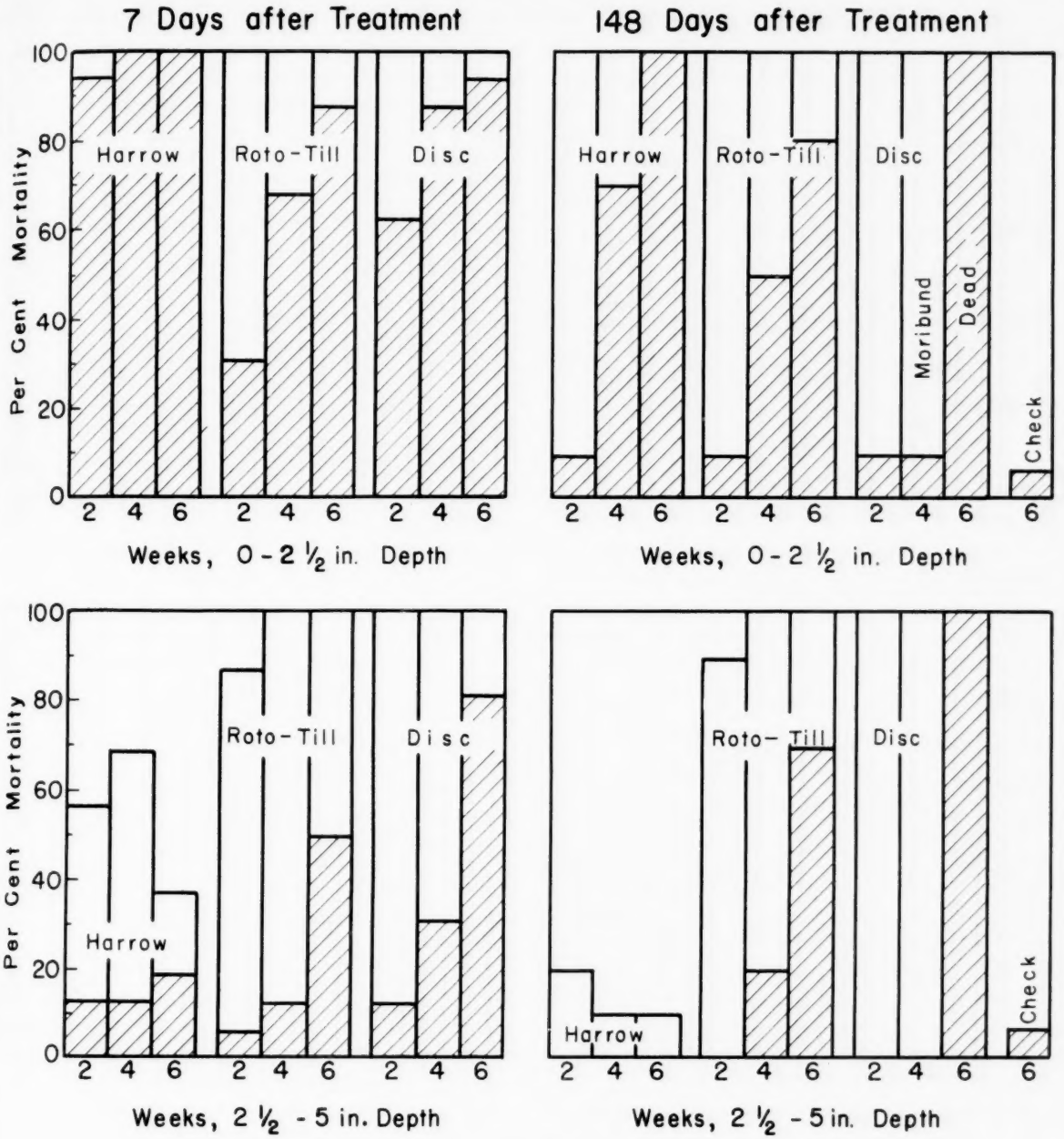


FIG. 3.—Wireworm mortality obtained from soil treated with 2 pounds of lindane per acre in relation to method of incorporation and persistence after treatment.

similar effects. As with aldrin, poor distribution was indicated with harrowing, but rotary tillage and discing gave similar effects. At 148 days harrowing gave the best initial effects at the 0 to 2.5-inch level, but at the 2.5 to 5-inch zone, rotary tillage and discing were superior.

Dieldrin at the upper zone when examined 7 days and 148 days after treatment showed little differences between the three tillage methods. At the lower level harrowing was again inferior (Fig. 4) in getting a uniform distribution, but rotary tillage and discing showed little difference at 7 and 148 days following treatment. That these differences are due to the distribution of the chemical is shown in table 1.

DDT at 20 pounds actual per acre in the upper 2.5 inches of soil showed best results by harrowing. As with the other chemicals DDT at the 2.5 to 5-inch level gave inferior kills in comparison with rotary tillage and discing. (Fig. 5).

In comparing the effectiveness of the four chemicals used in these particular tests and in this soil type it is evident that lindane at 2 pounds per acre was superior when evaluated against *Limonius canus* in the laboratory

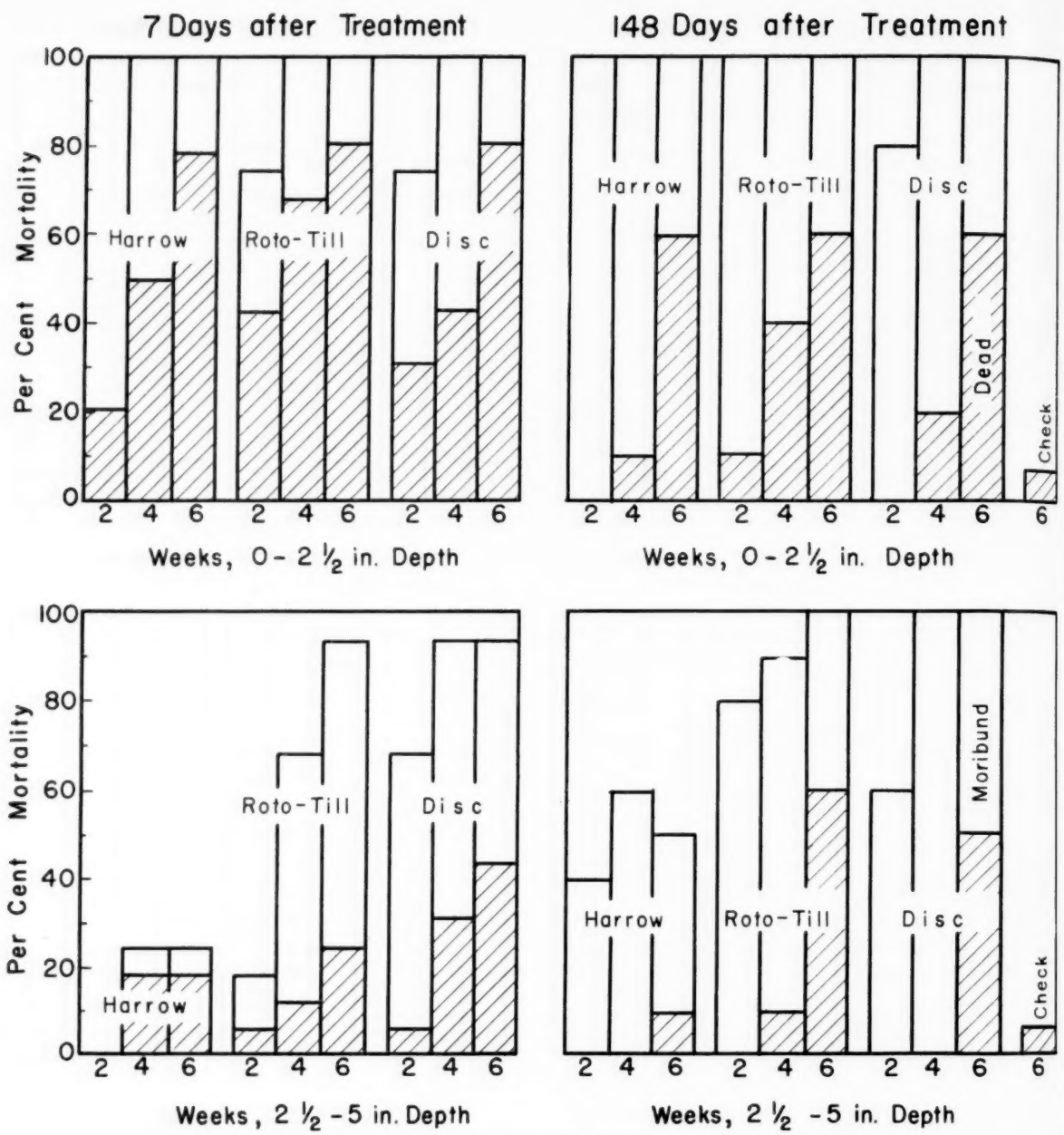


FIG. 4.—Wireworm mortality obtained from soil treated with 5 pounds of actual dieldrin per acre in relation to method of incorporation and persistence after treatment.

(Fig. 6). Aldrin at 10 pounds actual was next in effectiveness. DDT at 20 pounds and dieldrin at 5 pounds gave poorer kills due probably to their slower action. Aldrin at the 0 to 2.5-inch level lost an average of 44 per cent of the original amount applied when determined by chemical analysis (Table 1) 148 days following treatment. Dieldrin on the other hand during the same period lost only an average of 14 per cent. At the 2.5 to 5-inch level aldrin with rotary tillage lost 38 per cent of the original chemical applied at the end of 148 days, but no loss at this level for harrowing or discing. Dieldrin at the 2.5 to 5-inch level lost no chemical, but had an increase after 148 days. This would indicate some leaching to a lower depth.

Using lindane as an index of possible contamination of soil outside the boundaries of the plots, soil cores were taken at 10 to 12 inches, 3 feet, and 10 feet beyond the limits of the plots. Contamination was found only in the 10 to 12-inch zone beyond the plots. At an exposure period of 4 weeks, all wireworms were moribund or dead in soil at 10 to 12 inches beyond the plots, in the 0 to 2.5-inch zone. At the 2.5 to 5-inch level a 60 per cent mortality was

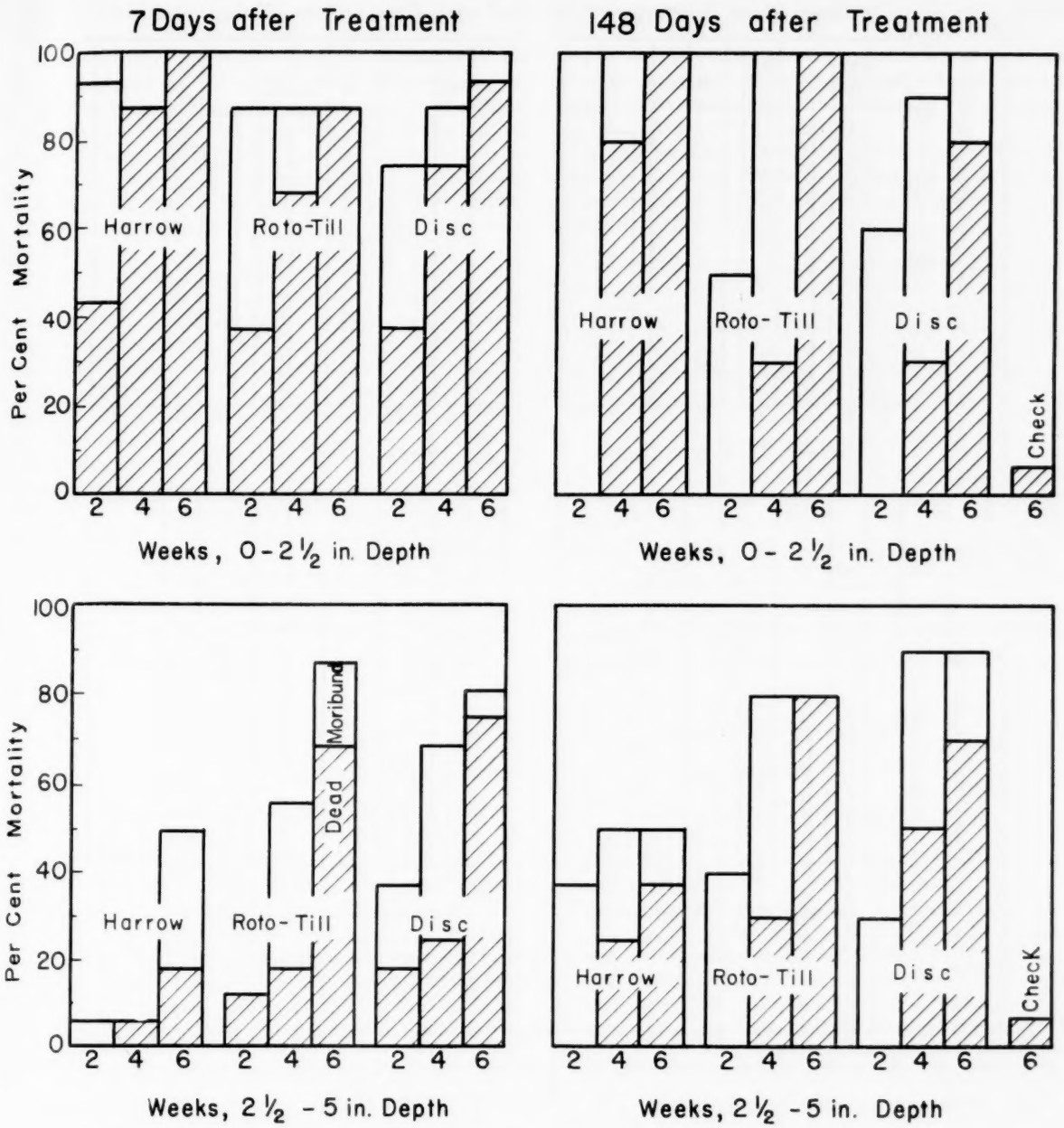


FIG. 5.—Wireworm mortality obtained from soil treated with 20 pounds of actual DDT per acre in relation to method of incorporation and persistence after treatment.

recorded. No contamination was found at 3 and 10 feet beyond the longitudinal boundaries of the plots.

CONCLUSIONS.—It seems apparent from the present experiments that of the three tillage methods used, harrowing, rotary tillage, and discing, that harrowing gave inferior dispersion of the chemicals when determined by means of bioassay tests on the Pacific Coast wireworm, *Limonius canus*, bioassay using house flies, and colorimetric analysis. With harrowing, 6 to 150 times as much of a particular chemical was found in the upper 2.5 inches of soil as contrasted with the lower 2.5 inches of soil. This resulted in a more rapid initial kill of wireworms in the upper 2.5 inches of soil. At the 2.5- to 5-inch zone, little toxicant and poor wireworm kills resulted.

Rotary tillage and discing dispersed more toxicant in the upper 2.5 inches than the next 2.5 inches. With aldrin for example, an average of 41 per cent more toxicant was found in the top 2.5 inches. With dieldrin an average of 74 per cent more toxicant was placed in the upper 2.5 inches of soil. Little consistent differences between rotary tillage and discing was observed when used as described.

It is difficult in these particular experiments to rate performance of these chemicals based on wireworm control due to the fact that only one concentration was used,

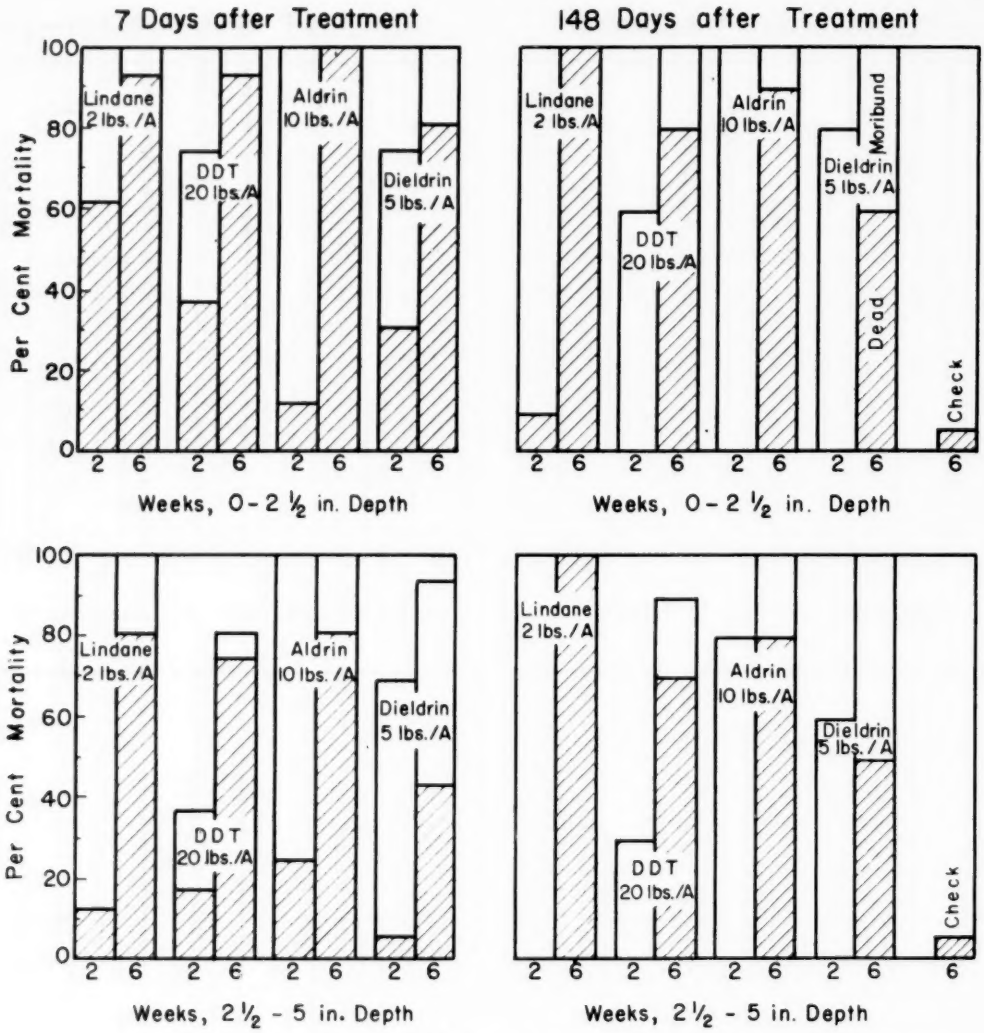


FIG. 6.—Wireworm mortality obtained from soil treated with four chemicals disced into the soil when taken at two depths and evaluated at two exposure periods.

Table 1.—Mortality of *Limonius canus* larvae in soil treated with aldrin and dieldrin in relation to laboratory bioassay evaluation and chemical analyses.

	Interval After Treatment											
	7 Days						148 Days					
Tillage Method	Harrow		Rotary Tillage		Disc		Harrow		Rotary Tillage		Disc	
Depth (inches)	0–2.5	2.5–5	0–2.5	2.5–5	0–2.5	2.5–5	0–2.5	2.5–5	0–2.5	2.5–5	0–2.5	2.5–5
					Aldrin							
Moribund (%)	19	25	6	25	0	19	10	40	40	22	10	20
Dead (%)	81	6	94	75	100	81	90	0	60	78	90	80
Total mortality (%)	100	31	100	100	100	100	100	40	100	100	100	100
P.p.m. toxicant[a]	0.98	<0.10	1.37	0.68	1.28	0.72	0.60	0.10	0.69	0.42	0.72	0.50
					Dieldrin							
Moribund (%)	21	6	19	69	19	50	40	40	40	40	40	50
Dead (%)	79	19	81	25	81	44	60	10	60	60	60	50
Total mortality (%)	100	25	100	94	100	94	100	50	100	100	100	100
P.p.m. toxicant[b]	3.00	0.02	1.70	0.22	1.30	0.01	2.40	0.22	1.35	0.64	1.31	0.54

[a] Average of 3 samples using colorimetric method.
[b] Average of 3 samples using bioassay of houseflies.

and differences in the velocity of action when checked according to the manner already described. However, it was apparent that lindane at 2 pounds and aldrin at 10 pounds per acre gave the best control of wireworms at most levels in the soils and observation dates.

SUMMARY.—Four different chemicals, lindane at 2 pounds per acre, aldrin at 10 pounds, dieldrin at 5 pounds, and DDT at 20 pounds, were applied to a Yolo clay loam soil arranged in randomized blocks. Three different tillage methods, spike tooth harrowing, rotary tillage, and discing were tested.

The distribution of chemicals in the soil was determined for 7 and 148 days following treatment, and at two levels in the soil, 0 to 2.5 inches and 2.5 to 5.0 inches. Methods used were a bioassay method using wireworms, a bioassay method using house flies, and a colorimetric method.

Harrowing was found to give the most unequal distribution of toxicants in the soil when determined by wireworm bioassay and a colorimetric method (aldrin). Rotary tillage and discing were found to give about equal mixing of chemicals in the soil, although 41 per cent more aldrin and 74 per cent more dieldrin was found in the upper 2.5 inches of soil in comparison with the lower 2.5 inches.

There was an average loss of 44 per cent of aldrin from the upper 2.5 inches of soil in 141 days when determined by a colorimetric method, as opposed to dieldrin with an average loss of only 14 per cent in the same period when determined by a bioassay method on house flies.

In wireworm control performance, lindane at 2 pounds per acre and aldrin at 10 pounds per acre gave higher mortalities at most levels in the soil and at two examination intervals following treatment.

Lindane was found to contaminate soil beyond the limits of the plots only to the extent of 10 to 12 inches; no contamination was found at 3 feet and 10 feet beyond boundaries of the plots.

ACKNOWLEDGEMENTS.—The authors would like to acknowledge the assistance of A. A. Danish of the former Julius Hyman & Company, and W. E. McCauley of the Shell Chemical Corporation, Denver, in making certain bioassay and chemical analyses in connection with this experiment. J. E. Knott and J. R. Laraway of the Department of Vegetable Crops, Davis, furnished land and assisted in the tillage operations.

REFERENCES CITED

Danish, A. A., and R. E. Lidov. 1950. A colorimetric method for estimating small amounts of aldrin (Compound 118). Anal. Chem. **22:** 702.

Hulbert, W. C., and R. G. Menzel. 1953. Soil mixing characteristics of tillage implements. Agr. Eng. **34**(10): 702–4, 706, 708.

Morrison, H. E., and H. H. Crowell. 1952. Soil insecticide studies in Oregon. Jour. Econ. Ent. **45**(6): 1002–10.

Investigations of Repellents for Protection Against Mosquitoes in Alaska, 1953[1]

ROBERT M. ALTMAN, *Medical Service Corps, U. S. Army,* and CARROLL N. SMITH,[2] *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*

Under the research program supported by the Army Committee for Insect and Rodent Control, several new repellents have been tested in recent years that show promise of being more effective than the materials previously used against various insects. They were initially selected from laboratory screening tests at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine, and cleared for restricted use on human subjects at the Army Environmental Health Laboratory, Detachment No. 1, at Orlando. After field tests at various localities in the Southern States, selected materials were tested in Panama against tropical species of mosquitoes and ticks. Since it was also deemed advisable to obtain information on their effectiveness against the subarctic species of mosquitoes, arrangements were made by the Office of the Surgeon General, Department of the Army, with the Commander in Chief, Alaskan Command, for a study in Alaska. It was conducted between June 3 and July 10, 1953. Logistical support was provided by the Alaskan Air Command and the U. S. Army, Alaska.

Six enlisted men from the 5005th Air Force Hospital assisted in conducting field tests near Anchorage and at various locations on the Kenai Peninsula between June 8 and June 17, and 10 enlisted men from the Medical Company, 4th Regimental Combat Team, near Chatanika, Alaska, between June 23 and July 8.

The species of mosquitoes encountered were mixed populations of *Aedes communis* (DeG.), *A. punctor* (Kirby), *A. excrucians* (Wlkr.), *A. fitchii* (F. and Y.), *A. stimulans* (Wlkr.), *Culiseta impatiens* (Wlkr.), and *C. alaskaensis* (Ludl.)[3] The *Culiseta* species were present in inconsequential numbers. Collections were made of the adults in each locality and of those that bit the treated arms, but there were no apparent differences in the effectiveness of the repellents against the various species.

MATERIALS TESTED.—Tests were made with 15 individual repellents and 12 repellent mixtures for application to the skin, and with 44 individual repellents and 6 mixtures for application to the clothing. The names of the repellents and the formulas of the mixtures are given in the

[1] This work was conducted under funds allotted by the Department of the Army to the Bureau of Entomology and Plant Quarantine. Accepted for publication September 30, 1954.

[2] The authors express their gratitude to the following officers for their assistance in these studies: Col. Carl E. Lundquist, Commanding Officer, 4th Regimental Combat Team; Lt. Col. Leland Keffer, Executive Officer, 5005th Air Force Hospital; Capt. Joseph Sweeney, Acting Surgeon, U. S. Army; Alaska; Capt. Gene A. Kieffer, Administrative Officer, Surgeon's Office, U. S. Army, Alaska; 1st Lt. Emery L. Bunn, Jr., Executive Officer, Medical Company, 4th Regimental Combat Team; and 1st Lt. Frank P. Skaggs, Jr., Regimental Surgeon, 4th Regimental Combat Team. Thanks are also due to Chester E. Poetsch, H. C. Stauffer, F. A. Oyer, and the management of Smith, Kline and French Laboratories for supplying the lotion formulations.

[3] Determinations were made by Dr. Alan Stone of the Bureau of Entomology and Plant Quarantine.

accompanying list, together with the Orlando code numbers. In the tables and the text the materials are identified by these numbers.

ORLANDO NO.	INDIVIDUAL REPELLENTS
262	Dimethyl phthalate
373	Ethanol, 2-(2-cyclohexyloxyethoxy)
375	1,3-Hexanediol, 2-ethyl-
2065	Hendecenoic (undecylenic) acid
2133	Cyclohexanol, 2-phenyl-
3341	Acetanilide, *N*-isopropyl-
3444	Anthranilic acid, *sec*-butyl ester
3775	1,3-Propanediol, 2-butyl-2-ethyl-
3897	Cyclohexene-1,2-dicarboxylic acid, diethyl ester
3916	Dimethyl carbate
4145	4-Cyclohexene-1,2-dicarboximide, *N*-butyl-
4203	Mandelic acid, isobutyl ester
4262	4-Morpholineacetic acid, isobornyl ester
5524	Acetanilide, *N*-propyl-
5949	2,4-Nonanediol
6168	Succinamic acid, *N,N*-diethyl-, propyl ester
6348	Succinamic acid, *N,N*-diisopropyl-, propyl ester
6369	Glutaramic acid, *N,N*-diethyl-, methyl ester
6484	Adipamic acid, *N,N*-diisopropyl-, methyl ester
6498	Cyclohexanecarboxylic acid, 1-hydroxy-, 2-butoxyethyl ester
6500	Cyclopentanecarboxylic acid, 1-hydroxy-, 2-butoxyethyl ester
6515	2-Cyclohexene-1-carboxylic acid, 2-methyl-4-oxo-6-propyl-, ethyl ester
6534	2-Cyclohexene-1-carboxylic acid, 6-ethyl-2-methyl-4-oxo-, ethyl ester
6555	Acetoacetamide, *N,N*-dibutyl-
7139	3-Octyne-2,5-diol, 2,5,7-trimethyl-
7209	4-Cyclohexene-1,2-dicarboximide, *N*-allyl-
7409	1,2-Cyclohexanedicarboximide, *N*-butyl-
7627	Carbostyril, 1-butyl-4-methyl-
8439	Bicyclo [2.2.1]-5-heptene-2,3-dicarboxylic acid, methyl propyl ester
10511	Propiophenone, oxime
12135	4,6-Decanediol, 5-ethyl-
13204	Caproic acid, 2-(2-hydroxy)ethyl ester
14249	Fencholic acid
14484	Lactic acid, butoxyethoxyethyl ester
15510	Senecioic acid, 2-[2-(2-butoxyethoxy)ethoxy] ethyl ester
17586	Benzamide, o-chloro-*N,N*-diethyl-
20023[a]	Citral malonic acid condensate #1
20034	3-Buten-1-ol, 1-(*o*-methoxyphenyl)-
20127	Mandelic acid, amyl ester
20188	Cyclohexanecarboxylic acid, 1-hydroxy-, 2-propoxyethyl ester
20217	*o*-Toluamide, *N,N*-diethyl-
20218	*m*-Toulamide, *N,N*-diethyl-
20224	Mandelic acid, propyl ester
20241	Mandelic acid, allyl ester
20293	Piperonyl alcohol, *alpha-tert*-butyl-
20297	Benzamide, *o*-ethoxy-*N,N*-diethyl-
	MIXTURES
M-250	Standard mixture—262 (60%), 375 (20%), Indalone (20%)
M-1960	3775 (30%), benzyl benzoate (30%), *N*-butylacetanilide (30%), Tween 80 (sorbitan monooleate, polyoxyalkylene derivative) (10%)
M-2020	262 (40%), 375 (30%), 3916 (30%)
M-2040	2065 (30%), 4145 (30%), *N*-butylacetanilide (30%) Tween 80 (10%)
M-2043	262 (40%), 375 (30%), 6168 (30%)
M-2044	262 (40%), 375 (30%), 17586 (30%)
M-2059	M-1960 (99%), lindane (1%)
M-2063	375 (50%), 20297 (50%)
M-2065	4145 (29%), 2065 (29%), 5524 (29%), lindane (3%), Tween 80 (10%)
M-2066	4145 (29.6%), 2065 (29.7%), 5524 (29.7%), lindane (1%), Tween 80 (10%)
M-2068	M-1960 (97%), lindane (3%)
M-2072	262 (40%), 375 (30%), 20297 (30%)
M-2073	262 (40%), 375 (30%), 20023 (30%)
M-2074	262 (40%), 375 (30%), 20218 (30%)
	LOTIONS
SKF No.	
C-7	M-2020 (40%), zinc oxide (10%), Deltyl Extra (a mixture of isopropyl myristate and isopropyl palmitate) (10%), Span 62 (sorbitan monostearate) (1.4%), Tween 60 (sorbitan monostearate, polyoxyalkylene derivative) (0.6%), distilled water (38%) (oil in water emulsion)
C-39	M-2020 (40%), zinc oxide (10%), Deltyl Prime (a mixture of isopropyl myristate and isopropyl palmitate) (10%), Span 80 (sorbitan monooleate) (2.4%), Tween 80 (1.6%), Pluronic F-68 (an ethylene oxide-propylene oxide condensate of propylene glycol) (1.75%), Veegum (a colloidal aluminum magnesium silicate) (0.25%), distilled water (34%) (oil-in-water emulsion)
C-39-t	Same as SKF C-39 but containing SKF Dermacolor II (a mixture of iron oxides) (0.3%), distilled water (33.7%) (oil in water emulsion)
I-1	Same as SKF C-39 but containing M-2072 (40%) instead of M-2020

[a] Compounds with numbers above 20000 were synthesized at the Beltsville, Md., laboratory of the Bureau of Entomology and Plant Quarantine.

TESTING METHODS.—Four of the individual skin repellents (262, 375, 3916, 6168) and one mixture (M-250) had been tested extensively in Alaska and elsewhere (Applewhite & Smith 1950, Applewhite & Cross 1951, Travis and Smith 1951), and were included as standards of comparison. Four of the mixtures (C-7, C-39, C-39-t, and I-1) were lotions formulated by the Smith, Kline & French Laboratories under a contract with the Department of the Army.

Four of the individual clothing repellents (3775, 4145, 4262, 7409) and one mixture (M-1960) had been tested in Alaska previously (Applewhite & Smith 1950), and were included as standards of comparison. The mixtures were designed for general use against various types of arthropods, and each contains some ingredients not outstanding as mosquito repellents but particularly effective against ticks, fleas, or mites. For this reason they were applied to the clothing at a heavier rate than the individual repellents.

The skin repellents were tested at various dilutions in ethanol because of the long protection periods obtained when applied at full strength. One milliliter of the solution was applied to the forearm from wrist to elbow, and the arm was exposed to natural infestations of mosquitoes. Arms treated with 1.25, 2.5, and 5 per cent solutions were exposed for 1 hour, or until 10 bites were received, and the number of bites per minute was computed. An untreated arm was exposed at intervals during the period to obtain the normal biting rate, on which an estimate of percentage repellency could be based.

Arms treated with 5, 10, and 25 per cent solutions were exposed until one or more bites were received or the tests were terminated because of rain, low temperatures, or cessation of biting. An attempt was made to continue testing until two bites were received within 30 minutes, but this did not always occur. Several times arms that

Table 1.—**Effectiveness of 1.25, 2.5, and 5 per cent solutions of repellents in skin applications against *Aedes* spp. during a 1-hour exposure period in Alaska.**

	CHATANIKA[a]				KENAI PENINSULA[b]			
	1.25 Per Cent		2.5 Per Cent		2.5 Per Cent		5 Per Cent	
REPELLENT NO.	Number of Bites	Per Cent Protection	Number of Bites	Per Cent Protection	Number of Bites	Per Cent Protection	Number of Bites	Per Cent Protection
262	0.34	93.2	0.14	98.3	0.21	97.9	—	—
375	.37	92.6	.09	98.9	.29	97.1	0.08	99.2
3916	.13	97.4	.11	98.6	.16	98.4	.09	99.1
6168	.12	99.6	.01	99.9	.10	99.0	.03	99.7
15510	.62	87.6	.06	99.3	.20	98.0	.02	99.8
17586	.18	96.4	.02	99.8	.06	99.4	.03	99.7
20023	.35	93.0	.02	99.8	.14	98.6	.07	99.3
20034	.50	90.0	.08	99.0	.27	97.3	.11	98.9
20127	.38	92.4	.08	99.0	.17	98.3	.10	99.0
20188	.50	90.0	.15	98.1	.24	97.6	.23	97.7
20217	.18	96.4	.04	99.5	.02	99.8	.00	100.0
20218	.07	98.6	.01	99.9	.03	99.7	.01	99.9
20224	.42	91.6	.07	99.1	.14	98.6	.06	99.4
20293	2.67	46.6	.17	97.9	.12	98.8	.12	98.8
20297	.52	89.6	.07	99.1	.19	98.1	.09	99.1
M-250	.35	93.0	.13	98.4	.39	96.1	.19	98.1
M-2020	.32	93.6	.14	98.3	.22	97.8	.03	99.7
M-2043	.27	94.6	.07	99.1	.09	99.1	.02	99.8
M-2063	.20	96.0	.06	99.3	.09	99.1	.05	99.5
M-2072	.17	96.6	.05	99.4	.14	98.6	.07	99.3
Check	5.00	—	8.00	—	10.00	—	10.00	—

[a] Five replications with individual repellents, 10 with mixtures.
[b] Three replications with individual repellents, 5 with mixtures.

were treated in the morning received several bites at intervals of 45 to 90 minutes during the early afternoon, but toward evening the mosquitoes avoided these arms completely, though still trying to bite untreated skin or clothing. Other treatments gave complete protection throughout the day. The time between treatment and the first bite was used as the protection period.

The lotions were tested in comparison with full-strength repellents by applying 0.5 ml. per forearm, and continuing exposure to determine the protection period.

In block tests the repellents were tested in blocks of five in comparison with the standard (M-250), and each repellent was tested once on the same three subjects.

In round-robin tests each repellent was paired against every other repellent on opposite arms of the same subject. In tests of this type it is possible to adjust the average protection period to allow for individual variation between hosts and testing conditions by using the formula

$$\text{Average } Ti = \frac{2\,Ti - Bi}{rn} + M$$

where Ti is the total protection time for all tests with repellent i, Bi is the total protection time for both repellents in all pairs in which repellent i occurred, n is the total number of repellents, r is the number of times each pair was replicated, and M is the grand mean of all protection times in the series.

Clothing repellents in acetone or gasoline solutions were applied to cotton stockings at the rate of 2 grams of the individual repellents per square foot and 3.6 grams of the mixtures. The stockings were exposed on the legs of three subjects in succession for 5 minutes each, or until an average of at least three bites per subject were obtained and at least two subjects had one or more bites. Tests were made after 1, 9, and 16 days of aging, and after 16 days of aging and 5 minutes of rinsing. During the aging period the stockings were hung on lines in a heated room. Rinsing was accomplished by submerging the stockings in the rapidly flowing Chatanika River.

RESULTS.—The results obtained with 1.25, 2.5, and 5 per cent solutions of the repellents are shown in table 1.

At Chatanika the most effective materials at 1.25 per cent were 20218, 6168, 3916, M-2072, 17586, 20217, M-2063, and M-2043, with biting rates from 0.07 to 0.27 per minute. At 2.5 per cent there were some differences in the order of effectiveness, but 20218, 6168, 17586, 20217, M-2072, M-2063, and M-2043 were still among the best materials, with biting rates of 0.01 to 0.07 per minute, as were also 20023, 15510, 20224, and 20297.

On the Kenai Peninsula normal biting rates were higher than at Chatanika. This is reflected in the higher biting rates on the various treatments. At 2.5 per cent 20217, 20218, 17586, M-2043, M-2063, 6168, M-2072, 20023, and 20224 were again among the best treatments, with biting rates of 0.02 to 0.14, as was 20293. At 5 per cent 20217, 20218, M-2043, 6168, 17586, M-2063, 20224, 20023, and M-2072 were again among the best compounds, with biting rates of 0 to 0.07, as were 15510 and M-2020.

Repellents included among the best in all four series of tests were 6168, 17586, 20217, 20218, M-2043, M-2063, and M-2072, and the best in three of the series were 20023 and 20224.

It was originally planned to test 10 per cent solutions by making 1-hour exposures and determining the biting rate, as in the weaker solutions, but it was soon apparent that the biting rates would be too low to provide a basis for comparison. Therefore, the protection period to the

Table 2.—Effectiveness of 10 per cent solutions of 15 individual repellents as skin applications against *Aedes* spp. in Alaska.[a]

Repellent No.	Protection Period (Minutes)[b]	
	Range	Average
262	59–141	115
375	71–114	99
3916	88–127	105
6168	111–300+	252+
15510	20–59	31
17586	164–300+	216+
20023	89–300+	198+
20034	57–329	164
20127	43–132	83
20188	20–169	72
20217	32–300	181
20218	252–300+	281+
20224	44–119	82
20293	19–68	50
20297	108–300+	208+

[a] Average of four tests.
[b] Plus marks in this and subsequent tables indicate that no bites had been received when the tests were terminated.

first bite was determined as shown in table 2. The longest protection periods were obtained with 20218, 6168, 17586, 20297, 20023, and 20217.

Results of block tests with 25 per cent solutions of the individual repellents and M-250 are presented in table 3. Subjects that had been showing the shortest protection periods in previous tests were used in block 1 and those with intermediate periods in block 2, whereas block 3 contained two subjects with long protection periods and one with short periods. This difference between hosts is reflected in the average protection periods with the standard (M-250) of 216 minutes in block 1, 239 minutes in block 2, and 235 minutes in block 3. The most suitable basis for evaluation of a repellent is therefore the ratio of its protection period to that of M-250 in the same block, since each repellent was tested on all the subjects in that block. Repellents with a ratio of more than 1.00 were 6168, 20218, 20297, and 17586.

Table 3.—Effectiveness of 25 per cent solutions of various repellents in block tests against *Aedes* spp. at Chatanika.[a]

Repellent No.	Protection Period (Minutes)		Ratio to M-250
	Range	Average	
	Block 1		
M-250	108–395	216	—
262	158–410	206	0.95
375	58–181	130	.60
3916	70–218	126	.58
6168	193–510+	327+	1.51+
15510	27–250	108	.50
	Block 2		
M-250	163–316	239	—
17586	149–389	271	1.13
20023	41–262	151	.63
20034	55–156	100	.42
20127	21–78	36	.15
20188	32–120	63	.26
	Block 3		
M-250	121–357	235	—
20217	121–239	174	.74
20218	400–480+	397	1.69
20224	75–304	209	.89
20293	34–92	55	.23
20297	229–480+	337	1.43

[a] Average of three tests.

Table 4.—Effectiveness of 25 per cent solutions of repellent mixtures in round-robin tests as skin applications against *Aedes* spp. at Chatanika.[a]

Mixture No.	Protection Period (Minutes)		Ratio to M-250
	Range	Adjusted Average	
M-250	267–349	269	—
M-2020	203–295	264	0.98
M-2043	306–399	343	1.28
M-2063	231–426	297	1.10
M-2072	153–443	311	1.16

[a] Average of four tests.

The relative effectiveness of five repellent mixtures is shown in the results of a round-robin series presented in table 4. Differences between the mixtures were not great, but M-2043 and M-2072 were slightly better than the others.

Table 5.—Results of round-robin paired tests with repellent mixtures and SKF lotions against *Aedes* spp. at Chatanika.

Paired Repellents	Protection Period (Minutes)	Paired Repellents	Protection Period (Minutes)
SKF C-7	395[a]	SKF C-39	495+
SKF C-39	399[b]	M-2072	210[a]
SKF C-7	495+	SKF C-39-t	495+
SKF C-39-t	495+	SKF I-1	401[c]
SKF C-7	122[b]	SKF C-39-t	185[b]
SKF I-1	144[b]	M-250	114[c]
SKF C-7	377[b]	SKF C-39-t	453[b]
M-250	410[b]	M-2020	379[b]
SKF C-7	495+	SKF C-39-t	163[b]
M-2020	263[a]	M-2072	363[b]
SKF C-7	495+	SKF I-1	495+
M-2072	495+	M-250	495+
SKF C-39	495+	SKF I-1	125[b]
SKF C-39-t	439[a]	M-2020	232[b]
SKF C-39	214[c]	SKF I-1	495+
SKF I-1	384[b]	M-2072	495+
SKF C-39	255[c]	M-250	495+
M-250	210[b]	M-2020	495+
SKF C-39	329[c]	M-250	495+
M-2020	394[b]	M-2072	495+
		M-2020	495+
		M-2072	495+

[a] Only one bite in 495 minutes.
[b] Additional bites within 30 minutes.
[c] Two additional bites within 40 to 200 minutes.

Table 6.—Results of paired tests with repellent mixtures and SKF lotions against *Aedes* spp. at Anchorage.[a]

10 Per Cent Solutions		Undiluted Mixtures	
Paired Repellents	Protection Period (Minutes)	Paired Repellents	Protection Period (Minutes)
M-250	165	SKF C-7	400+
M-2043	97	M-250	400+
M-250	154	SKF C-7	359[b]
M-2020	90	M-2020	400+
M-2020	188	SKF C-39	365
M-2043	146	M-250	315
M-250	149	SKF C-39	165[c]
M-2072	95	M-2020	361[b]
M-2072	277	SKF C-39-t	342
Check	—[d]	M-250	159
M-2020	126	SKF C-39-t	400+
M-2063	357	M-2020	400+
M-2063	335	SKF I-1	391[b]
M-2072	232	M-2072	400+
		SKF I-1	353
		M-2072	400+

[a] Additional bites were received within 30 minutes except as indicated.
[b] Only one bite in 400 minutes.
[c] Two additional bites in 165 minutes.
[d] Average of three bites per minute on an untreated arm.

The relative effectiveness of the SKF lotions and the full-strength repellent mixtures is shown by the data from Chatanika given in table 5. Almost half the tests had to be discontinued after 8 hours because of rain or cold before any bites were received. There was little difference between the effectiveness of the lotions and the mixtures.

Results of less complete tests with the lotions and other mixtures conducted near Anchorage (Elkutna) are given in table 6. The SKF lotions were slightly better than M-250, and slightly less effective than M-2020 and M-2072. In the tests with 10 per cent solutions M-2063 and M-2072 appeared better than the other three mixtures.

In the studies reported above compounds 6168, 20218, 20023, 17586, and 20297 have been outstanding. Compounds 6168 and 20237 had been included in two of the mixtures brought to Alaska for testing, M-2043 and M-2072, and it seemed advisable to incorporate the other three into similar mixtures. They were compared with M-2072 as a standard in 5 per cent solutions in round-robin tests, and the results are presented in table 7. Only mixture M-2074, containing 20218, was equal to M-2072, containing 20297.

Table 7.—Effectiveness of 5 per cent solutions of repellent mixtures in round-robin tests as skin applications against *Aedes* spp. at Chatanika.[a]

Mixture No.	Protection Period (Minutes)		Ratio to M-2072
	Range	Adjusted Average	
M-2072	31–240	111.5	—
M-2044	22–233	70.1	0.63
M-2073	21–128	79.2	.71
M-2074	61–242	119.1	1.09

[a] Average of six tests.

Table 8.—Effectiveness of stockings treated with various repellents against *Aedes* spp. after different periods of aging and rinsing at Eklutna and Chatanika.[a]

Repellent No.	After 16 Days' Aging	After 16 Days' Aging and 5 Minutes' Rinsing
2065	0	0.3
7627	0	.3
20293[b]	1.7	.3
20127	0	.4
M-2040	0	1.4
M-2066	0.1	1.5+
M-2065	.1	1.9+
4262	0	2.0+
M-1960	0	2.3+
6369	.4	2.7+
14249	0	2.7+
14484	0	2.7+
M-2068	0	2.7+
6348	0	2.8+
20219	.1	2.9+
3444	0	3+
3775	0	3+
4145	0	3+
5949	0	3+
6498	0	3+
6515	0	3+
6534	0	3+
7139	0	3+
7209	0	3+
7409	0	3+
13204	0	3+
15510	0	3+
17586	0	3+
20023[a]	0	3+
20034[c]	0	3+
20216	0	3+
20217	—	3+
20218[c]	0	3+
20241	0	3+
20297	0	3+
M-2059	0	3+
4203	.1	3+
6484	.1	3+
6500	.1	3+
6555	.1	3+
8439	.1	3+
20188[c]	.1	3+
373	.2	3+
5524	.2	3+
2133	.4	3+
10511	.4	3+
3341	.6	3+
20224	.6	3+
12135	.9	3+
3897	.9	3+

Average number of bites per exposure of three 5-minute exposures with each of three stockings. Exposures terminated at the third bite if three bites were received in less than 5 minutes.
[b] One stocking.
[c] Two stockings.

The results of the tests with stockings impregnated with repellents are given in table 8. In tests not shown in the table, all were completely effective after 1 day of aging and all but two after 9 days. These two, 7139 and 15510, allowed an average of 0.5 bite in 5 minutes. After

16 days a number of the treatments were permitting a few bites, but none were considered to have failed (three or more bites per subject). After 5 minutes of rinsing following the 16 days of aging the only treatments that did not fail in at least one replication were M-2065, 7627, 20127, M-2040, and 20293. Because of its poor record prior to rinsing the good showing of 20293 after rinsing is of doubtful validity; only enough of this material for a single replication was available.

In general, all the material provided a high degree of protection under experimental conditions in which they were not rubbed off.

SUMMARY.—Field tests with mosquito repellents were conducted in Alaska in June and July 1953 against mixed populations of *Aedes communis* (DeG.), *A. punctor* (Kirby), *A. excrucians* (Wlkr.), *A. fitchii* (F. and Y.), *A. stimulans* (Wlkr.), *Culiseta impatiens* (Wlkr.), and *C. alaskaensis* (Ludl.). Tests were made with 15 individual repellents and 12 repellent mixtures for application to the skin, and with 44 repellents and six mixtures for application to the clothing.

Because of the long protection periods obtained with repellents applied to the skin at full strength, comparisons were made of the biting rate at very low concentrations (1.25, 2.5, and 5 per cent) in ethanol and of the protection period at 5 to 25 per cent.

Clothing repellents in acetone or gasoline solutions were applied to cotton stockings, which were tested after 1 to 6 days of aging, and 16 days of aging plus 5 minutes of rinsing.

The five most effective individual repellents for application to the skin were *N,N*-diethyl-*m*-toluamide (20218); *o*-ethoxy-*N,N*-diethylbenzamide (20297); *o*-chloro-*N,N*-diethylbenzamide (17586); citral-malonic acid condensate #1 (20023); and propyl *N,N*-diethylsuccinamate (6168). The three most effective mixtures (M-2043, M-2072, and M-2074) each contained 40 per cent of dimethyl phthalate (262), 30 per cent of 2-ethyl-1,3-hexanediol (375), and 30 per cent of *N,N*-diethyl-*m*-toluamide (20218), *o*-ethoxy-*N,N*-diethylbenzamide (20297), or propyl *N,N*-diethylsuccinamate (6168).

The four lotions containing 40 per cent of repellent were about equal to full-strength repellent mixtures.

The three most effective individual repellents for application to clothing were hendecenoic (undecylenic) acid (2065), 1-butyl-4-methylcarbostyril (7627), and amyl mandelate (20127). The best mixture (M-2040) contained 30 per cent of hendecenoic acid (2065), 30 per cent of *N*-butyl-4-cyclohexene-1,2-dicarboximide (4145), 30 per cent of *N*-butylacetanilide, and 10 per cent of emulsifier (Tween 80).

REFERENCES CITED

Applewhite, K. H., and H. F. Cross. 1951. Further studies of repellents in Alaska. Jour. Econ. Ent. **44**: 19–22.

Applewhite, K. H., and Carroll N. Smith. 1950. Field tests with mosquito and sand fly repellents in Alaska. Jour. Econ. Ent. **43**: 353–7.

Travis, B. V., and Carroll N. Smith. 1951. Mosquito repellents selected for use on man. Jour. Econ. Ent. **44**: 428–9.

Rearing Citrus Red Mites in the Laboratory[1]

FRANCIS MUNGER,[2] *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*

In connection with studies on the biology of the citrus red mite, *Metatetranychus citri* (McG.), a method for rearing under controlled conditions in the laboratory was needed. The rearing cell used by McGregor & Newcomer (1928) and English & Turnipseed (1941), in which mites were reared on leaves of growing trees, did not lend itself to the experiments planned. Rearing in a screened insectary (Yust) was started before the laboratory experiments and proved relatively easy. Lemons used for host material were held in a wire letter basket, and transfers of mites were made by placing fresh lemons on the infested fruits and removing the oldest lemons from time to time as they became dry and hard. The initial insectary experience was the basis for developing the improved methods of handling the mites and host materials which were used later in the insectary and in the laboratory.

Lemons are used as host material. Green, somewhat rough fruits about 2½ inches in diameter, not recently sprayed, are always available in the field. They are held on special trays. These trays have a capacity of 10 lemons, are made of ¼-inch plywood 8×15½ inches, and have a double rim made of ¾×¾ inch stock glued on with resin glue to provide a trough ¾-inch square in cross section at the outer edge of the plywood. The tray, exclusive of the trough, is lined with thin plastic sheeting and filled with moist sand. A sheet of plastic material provided with ten ¾-inch holes is then placed over the tray and pressed into the trough and fastened with an adhesive around the outer edge. The holes are spaced to allow the 10 lemons to rest on the holes with their stems in the sand. Just before they are placed in the sand the stems are cut off close to the fruit. The trough is filled with water to keep the mites from wandering away from the tray, but it is possible for the mites to travel from one lemon to another within the 10-lemon unit. To facilitate estimating mite-population levels, eight circles ¾-inch in diameter are stamped with India ink on the surface of each lemon. For further aid in counting, these circles are divided into quarters. Population counts are made by removing the lemons one at a time by means of crucible tongs and holding them in the hand under a binocular microscope having a magnification of 10×.

ELIMINATION OF TYPHLODROMUS.—It had been found that predaceous mites of the genus *Typhlodromus* had an injurious effect on the mite population, and it was

[1] Accepted for publication September 30, 1954.
[2] The author is indebted to B. M. Broadbent for help in making population counts.

necessary to eliminate them from the host material. These predators were hidden under the sepals of the stem and were thus frequently brought in on the fruit from the field. Coating the stem end of the lemon with hot paraffin was tried. The *Typhlodromus* mites continued to live under the paraffin, and later, when the paraffin cracked as a result of lemon shrinkage, the predators emerged onto the lemon and began to feed on the red mites. The following procedure was then tried and has proved very effective:

A creamy paste of 50 per cent DDT wettable powder is painted around the base of each stem and worked underneath the sepals. After the paste is dry, both the blossom end and the stem end are dipped to a depth of ½ inch in melted paraffin at a temperature of approximately 175° F. The paraffin at both ends provides a handling surface relatively free of mites. At the stem end it seals in the DDT and prevents contamination of the lemon surface. The lemons are then brushed with a soft rotary brush to remove all eggs and mites outside the paraffined area which might have come in from the field.

EFFECT OF ENVIRONMENT.—In a satisfactory environment the mite population usually builds up to a rather high level and then, owing probably to food limitation, crowding, accumulation of webbing and of fecal material, some of the mites die, while others crawl off and fewer eggs are laid. In continuous rearing of the mites it is best to supply fresh food before too many have died. The method used to transfer the mites has been to place fresh lemons on a tray with a ½-inch-mesh wire fence about 3½ inches high around them. The old lemons are laid on top and are prevented from rolling off by the fence. When the desired transfer has been made, the old lemons and the fence are removed.

With this technique mites were reared continuously in the insectary for more than 2 years. They responded to seasonal conditions; in cold weather development was slow, but under favorable conditions the mites frequently became very numerous. The initial results indicated that the food supply and handling methods were satisfactory and that it should also be possible to rear them in large numbers under controlled conditions if the basic requirements of the mites were satisfied.

Attempts were made to rear the mites under a variety of conditions in the laboratory. At 90° F. and between 16 and 20 per cent relative humidity, on field-infested lemons, many eggs were laid, but none hatched and nearly all of the mites were dead after 2 weeks. At 90° F. and 61-68 per cent relative humidity, a considerable number of eggs were laid and many of them hatched. There was mortality in the larval and other stages, and all the mites were dead after about 7 weeks. Rooms held at 77° F. and either 60 to 70 or 80 per cent relative humidity were not at all satisfactory. The mites could sometimes be reared under these conditions for rather long periods of time, but population levels remained low.

Conditions of special interest were provided by a fluctuating temperature and humidity cabinet. The temperature ranged each day from approximately 86° to 64° F., and the relative humidity from 50 to 90 per cent. A small amount of moisture condensation was found on the fruits each day when the humidity was high and the temperature was rising. The mites were successfully reared in this cabinet for about 4 months. Transfers of mites were made during this period onto five successive groups of fresh lemons, but the mites were unable to become established on the sixth group and all finally died. Other trials with this cabinet were made with less success. The mites often continued to live for long periods, but the populations were generally low.

In one experiment in the room at 77° F. and 60 to 70 per cent relative humidity supplementary moisture was automatically applied to the fruit. This experiment was based partly on the observation that dew often occurs at night in the field during periods when the citrus red mite is building up to high levels. Infested lemons were given ½-minute mist sprays of distilled water 48 times at 15-minute intervals each day by means of an air brush controlled by a special time switch (Munger 1954). This supplementary moisture appeared to be beneficial. The unsprayed mites steadily decreased in numbers until they were all dead at the end of 8 weeks. The sprayed mites persisted, though at a rather low level, and were still alive at the end of 19 weeks, when the spray schedule was changed to 1-minute sprays 24 times at the same intervals.

This reduced number of spray applications was an improvement, but there was unaccountable mortality which showed that the conditions were not entirely satisfactory. The room used was large, 8×12 and 9 feet high, and it was thought, considering the relatively small amount of fruit and mites in it, that any special provision for ventilation would be unnecessary. The door to the room was opened frequently during the work, and there was a strong air-circulation system within. However, with a view to preventing any possible air stagnation or contamination, since the mites were dying from an unknown cause, beginning October 1, 1953, fresh air from out of doors was forced into the air-circulation system. With this ventilation the air brought into the room each hour was equivalent to approximately 2.5 times the capacity of the room. Immediately following the introduction of fresh air an improvement in the growth of mite populations was observed. In table 1 are summarized the results of mite rearing in the specially ventilated room without and with supplementary moisture. The numbers of eggs and mites shown are the average numbers present each week in the 80 count circles on successive groups of 10 lemons each.

The number of counts on each group of lemons ranged from two to five and depended generally upon the speed with which the mites used up the fruit. There were generally more eggs and mites on the sprayed lemons, and they required 16 groups of lemons while the unsprayed mites required only 14 groups in the same time. It appears that one of the keys to successful rearing of the citrus red mite is an abundance of fresh air. Periodic surface moisture on the host material is also beneficial.

In view of the pronounced beneficial effect of fresh air on the mites, an experiment was carried out to test the effect of a limited air supply on the mites. Two metal cabinets each having a capacity of approximately 7 cubic feet and the ventilated rearing room were tested simultaneously. Both cabinets were held at 77° F. and 60 to 70 per cent relative humidity. All the visible openings of one

Table 1.—Effect of supplementary moisture on citrus red mite populations[a] on lemons in a room having forced ventilation from out of doors, and held at 77° F. and 60 to 70 per cent relative humidity.

Observation Period	Without Supplementary Moisture		With Supplementary Moisture	
	Eggs	Mites	Eggs	Mites
Oct. 5–26	382	235	656	400
Oct. 19–Nov. 2	675	338	1206	499
Nov. 2–9	363	216	1195	355
Nov. 9–23	392	145	748	336
Nov. 23–Dec. 7	446	316	1144	728
Dec. 6–21	403	257	919	499
Dec. 21–Jan. 11	537	301	590	286
Jan. 11–25	1371	775	295	102
Jan. 25–Feb. 8	328	200	709	232
Feb. 8–22	422	242	873	638
Feb. 22–Mar. 1	484	388	1458	978
Mar. 1–15			881	499
Mar. 15–22	383	216	1422	1068
Mar. 22–Apr. 5			787	545
Apr. 5–12	360	170	706	475
Apr. 12–26	484	296	1186	774

[a] Average of weekly counts in 80 circles on 10 lessons.

cabinet were sealed, and the only exchange of air was through small cracks around the doors and once a week when the mites were removed for counting. The other cabinet received air from the rearing room continuously by means of a blower. Air equivalent to approximately 16 times the capacity of the cabinet was forced into it each hour. Eighteen infested lemons from the rearing-room stock were used for the source of mites. Six of them were used from January 12 to 19 to infest the first group of fresh lemons in each condition.

A population count on the source lemons was made on January 11. The numbers of eggs and mites, respectively, present in the 48 count circles on each group of 6 lemons were as follows:

	Eggs	*Mites*
Sealed cabinet	358	156
Circulating air cabinet	434	132
Rearing room	359	110

These counts on the source lemons show that the opportunities for infestation of the first group of lemons in each condition were approximately equal.

The source lemons were removed on January 19. By February 5 the mite populations were building up in the two circulating air conditions. A second group of fresh lemons was then supplied to each condition and left there until February 23. Population counts under the three conditions are shown in table 2.

This experiment reveals strikingly the need for circulation of fresh air in the rearing compartments. In the sealed cabinet the mites died out steadily. By the fifth week none were alive, and no mites had been able to establish themselves on the fresh lemons. In the other two

Table 2.—Effect of differences in air circulation on citrus red mite populations[a] on lemons held at 77° F. and 60 to 70 per cent relative humidity.

Observation Date	Sealed Cabinet		Circulating-Air Cabinet		Rearing Room	
	Eggs	Mites	Eggs	Mites	Eggs	Mites
Jan. 19	267	66	255	89	322	51
26	187	98	511	341	469	208
Feb. 2	63	18	551	360	430	265
9	4	3	156	124	270	135
16	0	0	91	24	123	91
23	0	0	57	40	203	38
	Fresh lemons started February 5					
Feb. 9	0	0	15	12	24	18
16	0	0	37	32	62	44
23	Discontinued		131	52	205	84
Mar. 2			311	224	416	228
9			576	360	434	354
16			292	260	151	175

[a] Weekly counts in 80 circles on 10 lemons.

conditions the mites continued to live and make successful transfer onto the fresh fruits.

This result is in keeping with the results of earlier rearing experiments in poorly ventilated rooms and cabinets, in which the need for fresh air has now been shown. But the function of the fresh air is obscure. Two possibilities are (1) an oxygen deficiency and a corresponding carbon dioxide increase caused by the respiration of the mites and the host material, and (2) contamination of the laboratory air by stored chemicals, but neither seems very probable. Another possibility is that the fruit, in ripening, may give off gases toxic to the mites. It is known, for example, that ethylene (Miller *et al.* 1940) and acetaldehyde (Biale & Shepherd 1940) are given off by ripening citrus fruits.

SUMMARY.—Laboratory tests in rearing the citrus red mite, *Metatetranychus citri* (McG.), have shown that an abundance of fresh air is necessary for continuously maintaining a healthy population. Periodic surface moisture on the host material is also beneficial. Mites were successfully reared in the laboratory for 7 months in a room held at 77° F. and 60 to 70 per cent relative humidity and provided with fresh air from out of doors.

REFERENCES CITED

Biale, J. B., and A. D. Shepherd. 1940. Identification of acetaldehyde among the volatile products of citrus fruit. Amer. Soc. Hort. Sci. Proc. **37**(1939): 543–7. Also in The Citrus Industry, Vol. 1, by Webber and Batchelor. Univ. of Calif. Press, 1943.

English, L. L., and G. F. Turnipseed. 1941. The influence of temperature and season on the citrus red mite (*Paratetranychus citri*). Jour. Agr. Res. **62**(2): 65–77.

McGregor, E. A., and E. J. Newcomer. 1928. Taxonomic status of the deciduous-fruit *Paratetranychus* with reference to the citrus mite (*P. citri*). Jour. Agr. Res. **36**(2): 157–81.

Miller, Erston V., J. R. Winston, and D. F. Fisher. 1940. Production of epinasty by emanations from normal and decaying citrus fruits and from penicillium digitatum. Jour. Agr. Res. **60**(4): 269–77.

Munger, F. 1954. Adaptable time switch. Science **120:** 671–2.

Yust, H. R. Unpublished notes.

Direct and Latent Toxicity of Insecticides to Oriental Fruit Fly Larvae and Their Internal Parasites[1,2]

MINORU TAMASHIRO and MARTIN SHERMAN,[3,4] *University of Hawaii, Agricultural Experiment Station, Honolulu, T. H.*

The use of insecticides to control insect pests has raised the problem of the deleterious effect of these insecticides on beneficial insects. It is generally considered that residual insecticides such as DDT are highly detrimental to parasitic insects while fumigants and labile poisons such as HCN, TEPP, and pyrethrum are less harmful since they volatilize or decompose rapidly.

While many studies have been reported in the literature concerning the effects of insecticides upon adults of various parasitic species of insects, there is a paucity of information on the effect of insecticides on the larvae of internal parasites while they are within the host. What little there is deals with the effect of fumigants (Froggatt 1905, Greene 1917), petroleum oils and insecticidal plant derivatives. Gosswald (1934) reported that pyrethrum killed the caterpillar of the nun moth but did not kill the parasites within them. When the adult parasites emerged, the pyrethrum had already broken down and these adults actually increased parasitization in the pyrethrum-treated plots. Noble (1935) in laboratory experiments sprayed aphids containing *Aphelinus mali* Hald. with miscible oil, nicotine sulfate and lime sulfur and obtained normal emergence of the parasites. Emergence continued for 17 days and since the pupation period for *A. mali* is 10 days, he concluded that some of the parasites were in the larval stage at the time of treatment. Ripper (1944) reported that short exposures of 40 to 60 seconds to nicotine vapors at temperatures of 60° to 80° F. killed the aphids but not the larvae of the braconid, *Aphidius* sp., an internal parasite of the aphids.

The present study is concerned with the oriental fruit fly, *Dacus dorsalis* Hendel, and one of its parasites, *Opius oophilus* Fullaway. The fly, first discovered in Hawaii in 1946, apparently was introduced accidently about 1943 or 1944 and within 3 or 4 years the population reached epidemic proportions. A biological control program was initiated in the Territory in 1947 and three internal hymenopterous parasites, *O. oophilus* Fullaway, *O. vandenboschi* Fullaway, and *O. longicaudatus* Ashmead were subsequently introduced and have become established (van den Bosch *et al.* 1951). *O. oophilus* is by far the most important of the three parasites, accounting for about 90 per cent of the parasitization. It oviposits in the eggs of the oriental fruit fly. The larva of the parasite remains in the first instar throughout the larval period of the host. After the host pupates, however, the development of the parasite accelerates and by the end of the larval period of the parasite, all of the host tissues except the mouth hooks are consumed. Pupation occurs within the host puparium and the adult parasite emerges approximately 10 to 12 days after pupation of the host (Haramoto 1953).

The fruit fly is protected from the action of insecticides during most of its larval period since in this stage it is located within the fruit. However, it leaves the fruit during the late third instar and enters the ground to pupate. If, in any extensive spray program, a residue of insecticide is built up in the soil due to drift and run off, it is possible for the larva to be exposed to lethal or sublethal doses of insecticide when it enters the soil.

Steiner & Hinman (1952) studied the effect of field application of insecticides on parasitization of the oriental fruit fly by opiines. They found that applications of aldrin and dieldrin lowered parasitization. As soil toxicants, L. F. Steiner and his associates found that dieldrin, aldrin, parathion, and BHC or lindane were promising in preventing pupation or emergence of the oriental fruit fly (Christenson 1953). Messenger (1951) compared the toxicity of insecticides to the fruit fly and its opiine parasites in the adult stage.

This study was undertaken to determine the differential effect of several synthetic organic insecticides on the immature stages of the oriental fruit fly and *Opius oophilus*.

MATERIALS AND METHODS.—The compositions of the compounds tested were as follows: parathion, technical, 96.5 per cent; aldrin, recrystallized, 99.3 per cent, m.p. 99.0–100.0° C. with sublimation; isodrin, recrystallized, 97.5 per cent, sublimes at 98° C.; dieldrin, recrystallized, 99.6 per cent, m.p. 164.0–167.0° C.; endrin, recrystallized, 96 per cent, sublimes with decomposition at 205.0° C.; chlordane, technical; BHC, gamma isomer, recrystallized, m.p. 113–113.5° C.; and DDT, pp′ isomer, recrystallized, m.p. 109.5–110.5° C. Stock solutions of these materials dissolved in redistilled acetone were prepared. Dilutions of these stock solutions with acetone were used in all experiments.

The mature third instar fruit fly larvae used in this study were reared in the laboratory. Papaya sections, about 2 inches in diameter and ¼ inch thick attached to glass slides with paraffin, were exposed to gravid adult flies in rearing cages for 20 to 45 minutes depending on the number of eggs desired. After exposure to the flies, the sections were placed for 24 hours in open end jars containing 50 females of the parasite, *Opius oophilus* Full. These jars were kept outdoors. Apparently the wind passing through the jars removed an odorous material produced by the parasites which in high concentrations partially inhibits oviposition (Haramoto 1953). Parasitization ranged from 30 to 70 per cent depending on the number of fruit fly eggs available in the papaya section. After 24 hours the sections were removed from the slides and placed in a blended carrot rearing medium modified somewhat from the one suggested by Finney (1953) by the addition of papaya and extra yeast. These additions helped insure an adequate food supply for the larvae. The parasitized larvae seemed to do especially well on

[1] Published with the approval of the Director of the Hawaii Agricultural Experiment Station as Technical Paper No. 329. Accepted for publication September 30, 1954.

[2] These data are a portion of the results of research presented by the senior author in the dissertation for partial fulfillment of the requirements for the M.S. degree in entomology at the University of Hawaii.

[3] The authors wish to acknowledge the assistance of the workers at the U.S.D.A. Fruit Fly Investigations Laboratory, Honolulu, Hawaii, and Frank H. Haramoto for supplying the adult flies and parasites.

[4] Presented at the Pacific Branch Meetings of the Entomological Society of America, Bend, Oregon, June 1954.

this medium. When the larvae reached maturity, they were washed out of the carrot medium by decantation and kept in water until ready for use. Although tests had shown that the larvae could remain in water for 48 hours without any ill effects, the larvae were not submerged for more than 12 hours.

Parasitized and unparasitized larvae were segregated on the basis of size and color. Parasitized larvae were almost always much smaller, about one-half to one-third the size of unparasitized larvae, and were lighter in color. Using these characters at least 95 per cent accuracy was obtained in the segregation of parasitized from unparasitized larvae.

Topical treatments.—A representative number of parasitized and unparasitized larvae were removed from water, dried on filter paper, inactivated with CO_2 and weighed. The weight of these larvae was used as the average larval weight of the population to be treated. During the course of this study, the average weight of the unparasitized larvae ranged from 14 to 18 mg. and parasitized larvae ranged from 6 to 9 mg. per individual. The larvae actually weighed were discarded.

Larvae to be treated were removed from the water, dried and kept under continuous anaesthesia with CO_2 as described by Williams (1946). Each larva was brushed onto a tin two-pronged fork which was adjusted so that the larva was held by its extremities. A measured drop of insecticide solution, 0.0006 ml. in volume, the maximum amount that could be applied to parasitized larvae without loss by runoff, was placed on the middle portion of the larva by means of a micropipette similar to that described by Roan & Maeda (1953). Throughout the study, the volume of the solution delivered was kept constant and the concentration was varied by diluting the stock solution. The acetone was allowed to evaporate before the treated larvae were dropped into 1-pint Mason jars containing damp sand. Parasitized and unparasitized larvae were kept in separate cheesecloth-covered jars and held until the adults emerged.

As soon as emergence started, a drop of honey was placed on the cheesecloth to provide food for the emerging adults. Three days after the start of emergence, the number of dead and moribund adult insects in the jar was recorded to determine latent toxicity.[5] After ascertaining that emergence was complete, the insects still alive in the jars were killed with chloroform, sifted out of the sand, and the total emergence of flies or parasites recorded to establish direct toxicity. All intact puparia were dissected to determine whether a parasite or a fly had died within the puparium. In ascertaining the mortality, flies that had started emergence but were not normal, that is, those that were only partially out of the puparium or those that were completely out but did not have their wings fully spread, were counted as dead. Such occurrences were common among the flies but rare among the parasites. Moribund insects that had completely emerged and were morphologically normal were counted as alive.

Dosage was calculated in terms of micrograms of toxicant per gram of larval weight. The dosage applied to the parasite was based on the weight of the parasitized fruit fly larva. Ten larvae per dosage level were used and each test was replicated at least three times.

When the tests were completed, the dosages were listed in a series of descending order of magnitude with the corresponding number of insects treated and dead. These dosages were combined by grouping them in fixed increments, the values of which depended upon the insecticide used. The observed mortalities were corrected for natural mortality by Abbott's formula (Abbott 1925). The median lethal dosages (LD-50) and their fiducial limits at the P = 0.05 level were calculated by the method described by Finney (1947).

Soil treatments.—Two hundred grams of beach sand were placed in pint Mason jars and 5 ml. of an acetone solution containing the required concentration of each insecticide were added and vigorously mixed with a spatula. The acetone was allowed to evaporate by letting the jars stand for about 6 hours after which 15 ml. of water were added to provide the larvae with sufficient moisture for pupation. The larvae used in this experiment were neither anesthetized nor weighed. When parasitized and unparasitized larvae were treated with the same concentration of insecticide, they were placed together in the same jar. The jars were held for the emergence of the adult insects and subsequent handling was similar to that described for the topical treatments.

Dosage was calculated in terms of micrograms of insecticide per gram of sand. Twenty larvae were used at each dosage level and each test was replicated at least three times.

RESULTS AND DISCUSSION.—*Topical treatments.*—Mortality resulting from the treatments fall into two categories. Toxicity is classified as direct when the insects are killed prior to completion of the pupal stage or before the emergence of morphologically normal adults. Toxicity is classified as latent (see below) when the insects are killed only after emerging as normal adults.

Table 1 summarizes the median-lethal dosages of the insecticides acting directly and their fiducial limits at P = 0.05. In comparing the results of direct toxicity to parasite and oriental fruit fly larvae, it may be noted that the former are half as susceptible to parathion, equally as susceptible to isodrin, and more susceptible to aldrin, endrin, chlordane, and lindane.

The median lethal dosage of dieldrin to the parasite was 3.30 μg./gm. but it was impossible to calculate the LD-50 for the fruit fly larvae. The data were extremely heterogeneous and could not be plotted with any degree of reliability. These erratic results probably were due to the insecticide being rubbed off the insect as it went down

[5] The term latent toxicity is defined on page 77.

Table 1.—Summary of the direct topical toxicity of several insecticides to larvae of Dacus dorsalis and Opius oophilus.

	Dacus dorsalis		*Opius oophilus*	
INSECTICIDE	LD-50 μg./gm.	Fiducial Limits P = .05 μg./gm.	LD-50 μg./gm.	Fiducial Limits P = .05 μg./gm.
Parathion	10.97	8.58– 14.04	25.2	15.6 – 40.8
Aldrin	156.6	110.8 –221.9	10.8	8.6 – 13.5
Isodrin	5.83	3.95– 8.61	10.5	8.5 – 13.2
Dieldrin	—	—	3.30	2.69 – 3.99
Endrin	5.64	4.66– 6.83	0.580	0.360– 0.935
Chlordane	3160	2919–3422	177.8	136.2 –232.1
Lindane	42.27	30.1 – 57.9	20.7	15.6 – 27.6
DDT	> 9800	—	> 9900	—

into the sand to pupate. At the higher dosages, a definite film of dieldrin could be seen on the larva and this may have cracked and sloughed off in the sand. The LD-50 was probably included within the dosages tested since, as will be discussed later, the soil treatments show that dieldrin is effective even at the low dosages.

The median lethal dosage could not be calculated for DDT. Both parasite and fruit fly larvae were highly resistant to the action of DDT. Although the dosages applied to the larvae were so great, 9900 μg./gm., that heavy deposits were visible, little or no mortality resulted. The ineffectuality of DDT applied topically was probably due to a lack of, or an extremely slow rate of penetration since workers at the U.S.D.A. Fruit Fly Investigations Laboratory in Honolulu have found that DDT when mixed with rearing media is toxic to larvae at concentrations as low as 5 to 10 p.p.m. (Roan & Maeda 1952).

Unlike the larva, the adult fruit fly is readily killed by DDT. Topical application of DDT at a dosage of 60 μg./gm. caused 100 per cent mortality within 24 hours of treatment.

Sun (1950) describes the toxicity index as a method for comparing the relative toxicity of insecticides. In comparing the relative potency of the insecticides to either parasite or oriental fruit fly larvae, parathion was taken as the standard insecticide and given an arbitrary index value of 100.

When compared with parathion in this manner, the toxicity indices for endrin, dieldrin, isodrin, aldrin, lindane, chlordane, and DDT for the parasite were: 4345, 764, 240, 233, 122, 14 and less than 0.2, respectively.

The toxicity indices for endrin, isodrin, lindane, aldrin, chlordane and DDT for the oriental fruit fly were: 194, 188, 26, 7, 0.3 and less than 0.1, respectively, when compared with the same standard insecticide.

There was a definite clinical pattern produced in the insects by the action of the insecticides. At and above the dosages of aldrin, isodrin, dieldrin, endrin, chlordane and lindane which resulted in 100 per cent mortality of the insects, most of the treated larvae did not penetrate the sand but died on the surface either as larvae or within partially formed puparia. At slightly lower dosages, metamorphosis continued until either the adult fly or the adult parasite was fully developed within the puparium before mortality occurred. Where unparasitized larvae were treated with still lower dosages, the adult fly partially or completely emerged, reached the surface of the sand and died before its wings were fully expanded. These flies were considered to be aborted.

Aborted adult parasites did not emerge from treated parasitized larvae. The parasites either emerged morphologically normal or did not emerge at all, dying in the pupal stage. The parasites were most susceptible during the latter part of their pupal development.

Parathion caused a different clinical pattern than that described above. With this insecticide, most of the treated larvae died shortly after formation of the puparium, apparently while still in the prepupal stage. The puparium of an insect killed by parathion was darker than normal and dissection showed it to be empty except for a small amount of dark viscous matter. Parathion probably killed the larvae soon after treatment so that the contents of the puparia dried out before they were dissected. Puparia of larvae killed by an insecticide other than parathion, however, were usually filled with liquid decomposed material.

Table 2.—Representative dosages of insecticide applied topically to unparasitized larvae of the oriental fruit fly illustrating the effect of latent toxicity on the surviving adults.

Material	Dosage, μg./gm.	Direct Toxicity[a] Corrected Per Cent Mortality	Latent Toxicity[a] Per Cent Mortality 3 Days After Emergence[b]
Parathion	22.8	80	25
	11.4	50	0
	3.78	21	0
Aldrin	578	73	100
	191	55	56
	34	23	37
Isodrin	26.9	90	100
	9.20	60	50
	2.76	10	47
Dieldrin	830	59	100
	166	35	68
	33.2	42	47
Endrin	18.1	87	100
	7.52	68	100
	2.67	22	90
Chlordane	3848	72	100
	3079	49	70
	2309	22	52
Lindane	106	73	12
	35.5	49	33
	17.7	25	9

[a] See text for explanation.
[b] Additional mortality in adult oriental fruit flies surviving direct toxicity.

The parasitized larvae affected by parathion in many instances did not form a normally shaped puparium. The abnormal puparium was elongated as if the host larva had died or become paralyzed before it had fully contracted to form the pupal case. In a few instances where such abnormal pupal cases were formed, the parasites developed into adults and even emerged. This further indicated that the host was killed early but that the parasite larva apparently was not affected.

Latent toxicity.—It was noted while observing the emergence of adult flies in the holding jars that some of these flies, although morphologically normal, exhibited typical symptoms of chlorinated hydrocarbon poisoning and died shortly thereafter. There apparently was a latent or delayed effect of these insecticides on the insects. Although the insects were treated while they were larvae, the complete toxic effect of the insecticide was not apparent until after the insect had become an adult. The term "latent toxicity" is proposed for this phenomenon.

Systematic observations of the latent toxicity to adult flies and parasites were made during the course of this study. Tables 2 and 3 summarize typical latent toxicity data obtained from the topical application of insecticides to unparasitized and parasitized oriental fruit fly larvae.

Table 3.—Representative dosages of insecticide applied topically to parasitized larvae of the oriental fruit fly illustrating the effect of latent toxicity on the surviving adult parasites.

Material	Dosage μg./gm.	Direct Toxicity[a] Corrected Per Cent Mortality	Latent Toxicity[a] Per Cent Mortality 3 Days After Emergence[b]
Parathion	37.3	63	0
	7.45	25	0
	5.59	17	0
Aldrin	17.2	63	54
	8.52	43	31
	6.38	33	11
Isodrin	39.4	93	50
	19.7	79	0
	8.81	30	0
Dieldrin	7.45	86	50
	3.28	52	21
	1.86	22	0
Endrin	0.976	57	50
	0.430	40	14
	0.233	35	0
Chlordane	410	76	57
	207	50	6
	87.3	26	14
Lindane	58.1	82	0
	38.7	68	0
	19.4	46	5

[a] See text for explanation.
[b] Additional mortality in adult parasites surviving direct toxicity.

The mortality resulting from direct toxicity occurring at the same dosage levels are included to indicate the increase in mortality due to latent toxicity.

This phenomenon was especially pronounced in endrin-treated fruit fly larvae. Where the lowest dosage of this material was used, adult flies emerged and appeared normal, but 90 per cent died within 24 hours after exhibiting typical symptoms of poisoning. Aldrin, dieldrin, isodrin, and chlordane also showed a high degree of latent toxicity, lindane showed very little, and parathion exhibited none.

This phenomenon was also observed occurring, although much less frequently among adult parasites. Parasites that had emerged were usually not affected. Aldrin, isodrin, dieldrin, endrin, and chlordane exhibited the highest degree of latent toxicity, although 57 per cent was the maximum.

The differential latent toxicity to the parasite and oriental fruit fly may be explained by one or both of the following:

1. The larvae, pupae and adults of the parasites detoxify the insecticide much more readily than do the corresponding stages of the flies.

2. The fly larva is much more resistant to the insecticide than is the adult fly, while there is probably little difference in resistance between the parasite larva and adult. The carry-over of insecticide from the larval stage may be sufficient therefore to affect the adult fly while not sufficient to affect the adult parasite.

Soil treatment.—Table 4 summarizes the median lethal dosages of the insecticides and their fiducial limits at P = 0.05.

The median lethal dosage could not be calculated for DDT. Both parasite and fruit fly were highly resistant to the action of DDT. Even at a dosage of 25,000 micrograms of DDT per gram of sand, adults emerged from 58 per cent of the parasitized larvae and 56 per cent of the unparasitized larvae. This amount of DDT caused the sand to turn white and become so encrusted that water could not penetrate it. It was necessary to work the water in with a spatula.

The parasites were more susceptible than the fruit flies to all the insecticides tested except parathion and isodrin. These two insecticides were equally toxic to both types of larvae. The toxicity index was used to compare the relative potency of the insecticides. Parathion was again taken as the standard insecticide with a toxicity index of 100. The toxicity indices for isodrin, aldrin, lindane, dieldrin, endrin, chlordane, and DDT for the parasites were: 183, 122, 100, 92, 61, 7, and less than 0.004, respectively. The toxicity indices for isodrin, endrin, aldrin, dieldrin, lindane, chlordane, and DDT for the oriental fruit fly were: 162, 42, 32, 24, 12, 0.9 and less than 0.0005 respectively.

The same general clinical pattern that occurred in the topical treatments was produced in the insects by the soil treatments. In preliminary experiments, a dosage of 5000 μg./gm. of aldrin, isodrin, dieldrin, endrin, chlordane and lindane demonstrated a repellent effect on the larvae. The larvae bored into the sand as soon as they were placed in the jar but returned to the surface within ½ hour. Most of these larvae pupated on the surface within 48 hours but a few died as larvae after 72 hours. The puparia dissected some time later were found to be empty. Sand treated with DDT at the rate of 25,000 μg./gm. had no repellent effect on the larvae.

In every instance, the insecticides when used as soil treatments caused more insects to die as fully developed adults within the puparia than when applied topically.

Summary.—The relative toxicities of parathion, aldrin, isodrin, dieldrin, endrin, chlordane, lindane and DDT to parasitized and unparasitized third instar larvae of *Dacus dorsalis* Hendel were investigated. The parasite used in this study was *Opius oophilus* Fullaway.

Table 4.—Summary of the toxicity of several insecticides applied as soil treatments to larvae of Dacus dorsalis and Opius oophilus.

Insecticide	*Dacus dorsalis* LD-50 μg./gm.	*Dacus dorsalis* Fiducial Limits P = .05 μg./gm.	*Opius oophilus* LD-50 μg./gm.	*Opius oophilus* Fiducial Limits P = .05 μg./gm.
Parathion	0.13	0.11– 0.15	0.11	0.09–0.14
Aldrin	0.41	0.32– 0.54	0.09	0.07–0.12
Isodrin	0.08	0.07– 0.10	0.06	0.05–0.07
Dieldrin	0.53	0.44– 0.64	0.12	0.09–0.17
Endrin	0.31	0.28– 0.35	0.18	0.16–0.20
Chlordane	13.8	10.9 –17.4	1.6	1.4 –1.9
Lindane	1.1	0.98– 1.2	0.11	0.10–0.13
DDT	>25000	—	>25000	—

The insecticides were applied topically and as soil treatments. In the topical treatments, parasites were less susceptible than oriental fruit flies to parathion, equally susceptible to isodrin and more susceptible to aldrin, endrin, chlordane, and lindane. Both parasites and fruit flies were highly resistant to DDT.

The action of the insecticides produced definite clinical patterns in the insects. With aldrin, isodrin, dieldrin, endrin, chlordane, and lindane it was possible to kill the insects as larvae, pupae, and fully developed adults within the puparia or to cause the emerging adult flies to be abnormally developed, depending on the dosage level used. Abnormally developed adult parasites did not emerge from the treated parasitized larvae.

Parathion caused a different clinical picture. Most of the larvae treated with this insecticide died shortly after forming the puparium. In many instances the parathion-treated parasitized larvae formed abnormal, elongated puparia as if the host larvae had died or become paralyzed before they had fully contracted to form the puparia. Occasionally when this occurred an adult parasite developed and emerged.

The term *latent toxicity* is proposed for the condition in which the larvae are treated with insecticide but the toxic effect does not fully manifest itself until after the insect becomes an adult. Latent toxicity was exhibited by aldrin, isodrin, dieldrin, endrin, chlordane, and lindane. The phenomenon was especially pronounced in endrin-treated insects. Symptoms of latent toxicity were exhibited much less frequently by the parasites.

In the soil treatments, the parasites and fruit flies were equally susceptible to parathion and isodrin but the parasites were more susceptible to aldrin, dieldrin, endrin, chlordane, and lindane. Both parasites and fruit flies were highly resistant to DDT.

The same general clinical pattern that occurred in the topical treatments was produced in the soil treatments.

REFERENCES CITED

Abbott, W. W. 1925. A method of computing the effectiveness of an insecticide. Jour. Econ. Ent. **18**: 265–7.

Christenson, L. D. 1953. Status of oriental fruit fly investigations in Hawaii. Third Special Rpt. on the control of the oriental fruit fly in the Hawaiian Islands. Senate of the State of California. pp. 33–50.

Finney, D. J. 1947. Probit analysis, a statistical treatment of the sigmoid response curve. xiii+256 pp. Cambridge University Press, Cambridge, England.

Finney, G. L. 1953. A summary report on the mass-culture of fruit flies and their parasites in Hawaii. Third Special Rept. on the control of the oriental fruit fly in the Hawaiian Islands. Senate of the State of California. pp. 77–83.

Froggatt, W. W. 1905. Effects of HCN on parasites of *Icerya*. Agr. Gaz. N. S. Wales **16**: 1088–9.

Gosswald, K. 1934. Zur Biologie und Okologie von *Parasitigena segregata* Rond. und *Sarcophaga Schutzei* Kram. (Dipt.) nebst Bemerkungen über die fortliche Bedeutung der beiden Arten. Zeit. Ang. Ent. **21**: 1–23.

Green, E. E. 1917. Notes on the immunity of chalcid parasites to hydrocyanic acid gas. Ann. Appl. Biol. **4**: 90.

Haramoto, F. H. 1953. The biology of *Opius oophilus* Fullaway (Braconidae: Hymenoptera). Master's Thesis. University of Hawaii.

Messenger, P. S. 1951. Effect of insecticides on *Opius vandenboschi* Full. Hawaii Agr. Exp. Sta. Ent. Dept. Quarterly Report. Jan.–March, 1951.

Noble, N. S. 1935. The woolly aphid parasite. Agr. Gaz. New South Wales. **46**(10): 573–5.

Ripper, W. E. 1944. Biological control as a supplement to chemical control of insect pests. Nature **153**: 448–52.

Roan, C. C., and S. Maeda. 1952. Potential resistance of oriental fruit fly to DDT. Investigations of fruit flies in Hawaii U.S.D.A. Quarterly Report. July–September. 1952: 60.

Roan, C. C., and S. Maeda. 1953. A microdevice for rapid application of toxicants to individual insects. BEPQ. U.S.D.A. **ET-306.**

Steiner, L. F., and F. Hinman. 1952. Field tests of insecticides for control of oriental fruit fly. Jour. Econ. Ent. **45**(3): 388–95.

Sun, Y. P. 1950. Toxicity index—an improved method of computing the relative toxicity of insecticides. Jour. Econ. Ent. **43**(1): 45–53.

van den Bosch, R., H. A. Bess, and F. H. Haramoto. 1951. Status of oriental fruit fly parasites in Hawaii. Jour. Econ. Ent. **44**(5): 753–9.

Williams, C. M. 1946. Continuous anesthesia for insects. Science **103**: 57.

Distribution and Incorporation of Radioactive Phosphorus in the Douglas-Fir Beetle[1,2]

S. C. FANG, *Oregon State College, Corvallis,* and DON ALLEN, *Oregon State Board of Forestry, Salem*

Radioactive materials as tracers have been used by many investigators in studies concerning the metabolism and distribution of elements in the insect body. Lindsay & Craig (1942) added P^{32} to the food to study the distribution of this isotope in several insects. Both frozen and paraffin sections were used to obtain the autoradiograms. In all the insects, the P^{32} was least concentrated in the fat body and most concentrated in the epithelium of the mid-intestine, in the reproductive ducts and in the gonads. Wheeler (1950) who studied the distribution of I^{131} in *Drosophila gibberosa*, found the major part of radioiodine in the skeletal parts of the flies. Bowen (1949) and Bowen *et al.* (1951), recently made studies on the metabolism of Ba^{140} and La^{140} in hornets and wasps. They found

[1] This work was supported in part by a grant from the Atomic Energy Commission and Forest Protection and Conservation Committee.

[2] Approved for publication as Technical Paper No. 869 by the Director of the Oregon Agricultural Experiment Station. Contribution of the Department of Agricultural Chemistry. Accepted for publication October 8, 1954.

Table 1.—Distribution of P^{32} in beetles after feeding for 2 days with a sugar solution containing 2.5 μc. of P^{32}.

Insect No.	Head		Thorax		Abdomen		Legs		Wings		Total
	cpm	Per Cent	cpm	Per Cent	cpm	Per Cent	cpm	Per Cent	cpm	Per Cent	cpm
1	653	18.3	712	20.0	1554	43.6	223	6.3	413	11.6	3555
2	1190	17.3	1020	14.8	3500	50.7	543	7.9	640	9.3	6893
3	411	15.1	448	16.4	1512	55.4	143	5.2	220	8.1	2734
4	938	17.9	605	11.6	2882	55.1	359	6.9	432	8.3	5216
5	393	13.6	558	19.3	1382	47.8	222	7.7	339	11.7	2894
6	702	17.9	428	10.9	2382	60.6	158	4.0	263	6.7	3933
7	430	13.9	482	15.6	1682	54.4	175	5.7	325	10.5	3094
8	868	19.8	411	9.4	2280	52.0	359	8.2	465	10.6	4383
9	596	14.8	472	11.7	2200	54.6	281	7.0	477	8.4	4026
10	732	17.0	448	10.4	2400	55.8	388	9.0	326	7.6	4294
Average		16.6±1.8		14.0±3.2		53.0±3.6		6.8±1.2		9.3±1.5	4102

that hornets will accumulate barium when exposed to infinitesimal amounts. The La^{140} was not absorbed by this insect nor did it appear to be excreted when formed in the body by decay of Ba^{140}.

During 1949–1952, more than 10 billion board feet of Douglas fir timber were damaged by the Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopkins, in Oregon and Washington (Greeley *et al.* 1953). Too little information exists in the bionomics and biodynamics of this insect to provide a basis for practical methods of control. Therefore a series of investigations utilizing radioisotopes was carried out which included physiological studies, methods of tagging and biological effects of irradiation.

This report describes the results on the distribution and incorporation of radioactive phosphorus into the insect body and the phosphorylated intermediate compounds. It seemed that this information would not only be of interest from the standpoint of phosphorus metabolism of this insect but would also provide a convenient basis for comparative work on the phosphorus metabolism of some other insects.

Materials and Methods.—Radioactive phosphorus

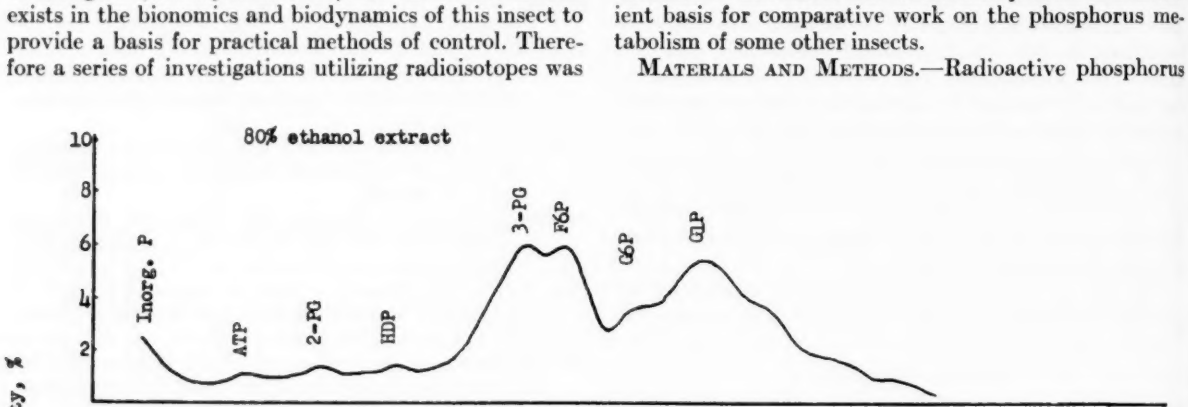


Fig. 1.—Radioactivity pattern of paper chromatograms made from 80% ethanol and hot water extracts of Douglas-fir bark beetles fed with radioactive phosphorus.

Table 2.—Incorporation of P^{32} into phosphorylated intermediates from the extracts of beetles[a] after feeding for 2 days with a nutrient medium containing radioactive phosphorus.

		Ether Extract	80% Ethanol Extract	Hot Water Extract	Residue	Total	R_f Values Reported in Literature
P^{32} activity	cpm	7,150	96,500	71,510	30,850	206,000	
	Per cent	3.5	46.8	34.7	15.0	100	
Results from *Chromatographic Separation*	R_f Range						
Ino. P	0.00	85%	6.7%	53.5%		24.74%	.05
ATP	.10–.13		1.8	5.8		2.86	.15
2-P-G	.17–.21		3.8	12.3		6.05	.18
F-D-P	.23–.26		3.6	20.7		8.89	.24
3-P-G	.33–.37		30.7	1.1		14.78	.35
F-6-P	.39–.41		12.7	1.6		6.51	.44
G-6-P	.45–.48		9.8	1.7		5.18	.48
G-1-P	.54–.58		19.7	2.2		10.00	.60
unidentified	.74–.78		2.1	0.8		2.9	
phospholipid	.85	6				0.21	

[a] One hundred and twenty five beetles were used.

in the form of phosphoric acid obtained from Oak Ridge, Tenn., was used in this study. The radioactivity was measured by means of a thin mica window Geiger-Müller counter (1.9 mg./cm.^{2}) and a Tracerlab utility scaler. The whole insect or insect part was counted directly in a cupped planchet. A direct plating method was used to measure the activity of extracts. No corrections for self-absorption were made. All measurements were made to an accuracy of 5 per cent or better. Only adult beetles which were collected from the infested Douglas fir bark were used. Some of these were stored at 2° C. for several weeks before used. No attempt was made to control the sex and age of the beetles used in this experiment.

DISTRIBUTION OF RADIOACTIVE PHOSPHORUS IN BEETLES FED WITH FOOD CONTAINING P^{32}. A number of beetles were fed with a 2.5 per cent glucose solution containing 2.5 μc. (micro-curie) of P^{32} per milliliter. After 2 days of feeding the radioactivity of each beetle was measured, and an average activity of about 4000 counts per minute (cpm) was shown. The beetles were then washed several times, first with a very dilute phosphate solution and then with water to determine how much of the radioactivity could be removed. Only 2 per cent of the activity was lost by washing, indicating that nearly all of the P^{32} was incorporated in the insect. Ten beetles were dissected and the radioactivity of each part was measured to determine the distribution of P^{32} in the beetle. The results are tabulated in table 1.

INCORPORATION OF RADIOACTIVE PHOSPHORUS INTO PHOSPHORUS CONTAINING COMPOUNDS FROM BEETLES FED WITH P^{32}. One hundred twenty-five beetles which had been fed with food containing P^{32} for 2 days were ground and extracted successively with ether, 80 per cent ethanol and boiling water. Each succeeding solvent was used only when there was no appreciable amount of activity extractable by the solvent being used. The radioactivity of the extracts was determined by the direct plating method in a stainless steel cup. An aliquot of 0.5 milliliter was used in each case.

Paper chromatography was used to study the incorporation of P^{32} into the phosphorylated intermediates. The extract, containing enough radioactivity for an accurate measurement, was applied to a spot about 7 cm. from the end of a strip of Whatman #1 filter paper (1″×22″) by means of a fine eye dropper. The chromatograms were developed with a basic methanol solvent (MeOH, NH_4OH, H_2O, 6:1:3 v/v) according to Bandurski & Axelrod (1951) at 2° C. for 15 to 16 hours. After drying, the chromatogram was cut into 1-cm. sections starting from the original spot and the radioactivity of each section was measured. The radioactivity pattern of paper chromatograms of both 80 per cent ethanol and hot water extracts are represented in figure 1. The relative radioactivity of each spot was computed according to Jaworski & Butts (1952). The average values are recorded in table 2. A few authentic samples of inorganic phosphate, adenosine triphosphate, fructose 1,6-diphosphate, glucose 1-phosphate, and 3-phosphoglycerate were run and subsequently the phosphate color was developed to check the R_f values. The technique of Hanes & Isherwood (1949) using perchlorate-molybdate reagent was followed. All the R_f values obtained checked very closely with Bandurski's results. One radioactive spot having an R_f value between .39–.41 is believed to be fructose-6-phosphate which is slightly lower than the value .44 reported by Bandurski. Another spot appearing at R_f .74–.78 has yet to be identified.

RESULTS AND DISCUSSION.—The results in table 1 show the distribution of P^{32} activity in different parts of insect body. Approximately 9.3 per cent of the total activity was found in the wings. The results differed somewhat from the reports made by Hoffman *et al.* (1951), Yates *et al.* (1951) and Hassett & Jenkins (1951) using house flies and mosquitoes, in which less than 2 per cent of P^{32} was present in the wings.

When P^{32}-fed beetles were ground and extracted with ether, only 7150 counts per minute or 3.5 per cent of the total P^{32} activity was extractable. A very small amount of P^{32} was found incorporated into the phospholipids. This result agreed very well with the finding of Lindsay & Craig (1942) that the P^{32} was least concentrated in the fat body of all the insects they had examined. Forty-

seven per cent of the P^{32} was extracted by 80 per cent ethanol, 34.7 per cent by hot water and 15 per cent remained in the residue. All phosphorus intermediates can be identified from the radioactivity pattern of both paper chromatograms made respectively from alcohol and water extracts. In the alcohol extract, about 93 per cent of the P^{32} activity was incorporated into different phosphorylated intermediates. 3-Phosphoglycerate has the highest concentration, next are glucose 1-phosphate, fructose-6-phosphate, and glucose 6-phosphate. In the hot water extract, more than one-half of the P^{32} is in the inorganic form. The per cent distribution of P^{32} in different phosphorylated intermediates in the insect body is represented in table 2. Since no information is available regarding the incorporation of phosphorus in other insects, no comparison can be made at the present time. It is safe to state, however, that a glycolytic cycle must be present in the beetle, since most phosphate esters which are known to be intermediates of glycolysis were found to be present in the beetles.

SUMMARY.—The distribution of P^{32} in different parts of the body of Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopkins, and its incorporation into phosphorylated intermediates was studied. Most phosphate esters which are known to be intermediates of glycolysis were found to be present in the beetle.

REFERENCES CITED

Bandurski, R. S., and B. Axelrod. 1951. The chromatographic identification of some biologically important phosphate esters. J. Biol. Chem. **193**: 405–10.

Bowen, V. T. 1949. Barium metabolism in hornets studied by means of radioisotopes. Trans. N. Y. Acad. Sci. **2**(11): 68–72.

Bowen, V. T., A. C. Rubinson, and D. Sutton. 1951. The uptake and distribution of barium-140 and the lanthanum-140 in larvae of *Drosophila repleta*. J. Exptl. Zool. **118**: 509–29.

Greeley, A. W., K. H. Wright and R. B. Pope. 1953. Final report on the 1952 blowdown. Bark beetle survey in the Douglas-fir region of Oregon and Washington. U.S.D.A.

Hanes, C. S., and F. A. Isherwood. 1949. Separation of the phosphoric esters on the filter paper chromatogram. Nature **164**: 1107–12.

Hassett, C. C., and D. W. Jenkins. 1951. The uptake and effect of radiophosphorus in mosquitoes. Physiol. Zool. **24**: 257–66.

Hoffman, R. A., A. W. Lindquist and J. S. Butts. 1951. Studies on treatment of flies with radioactive phosphorus. Jour. Econ. Ent. **44**(4): 471–3.

Jaworski, E. G., and J. S. Butts. 1952. Studies in plant metabolism. II. The metabolism of C^{14}-labeled 2,4-Dichlorophenoxyacetic acid in bean plants. Arch. Biochem. & Bioph. **38**: 207–18.

Lindsay, E., and R. Craig. 1942. The distribution of radiophosphorus in wax moth, meal worm, cockroach and firebrat. Ann. Ent. Soc. Amer. **35**: 50–6.

Wheeler, B. M. 1950. Halogen metabolism of *Drosophila gibberosa*. 1. Iodine metabolism studied by means of I^{131}. J. Exptl. Zool. **115**: 83–108.

Yates, W. W., C. M. Gjullin, A. W. Lindquist and J. S. Butts. 1951. Treatment of mosquito larvae and adults with radioactive phosphorus. Jour. Econ. Ent. **44**(1): 34–7.

Speedlight Calibration for Photography of Small Opaque Objects[1]

LELAND R. BROWN, *Department of Entomology, University of California, Los Angeles*

New methods of low-cost color printing (Clark 1952) are being developed which, it is hoped, will be of use to scientific journals. Few fields of science surpass entomology in the need for such developments and the entomologist should be ready to make use of these new methods when desirable. The necessity of having properly exposed low power photomicrographs is readily apparent when publication by such methods, or even conventional color printing methods, is considered. But even if a series of color transparencies is never published, its use in conventional projection is very annoying, and may be misleading, if transparencies within the series vary from under- to over-exposure. It is hoped that the present paper will contribute to the ease and certainty of obtaining properly exposed low power photomicrographs.

The speedlight (also known as high-speed flash, electronic flash, and strobelight) is being used by a number of workers in photographing small objects, such as insects and insect-damaged plant parts. The advantages and use of the speedlight for certain of such situations have been described (Brown 1954) as well as a method for calibrating the speedlight. The method described was based partially on the assumptions that the reflector, as normally supplied with the speedlight, could be detached allowing the apparent radiating source to approximate a point source and thus obey the inverse square law of illumination. The findings in the present paper indicate that this latter assumption was not entirely correct. Also many speedlights currently produced have the reflector made as an integral part of the lamp, so that the lamp cannot be used without the reflector.

The present paper describes a method of calibrating any speedlight for use in small object photography by reflected light. It is likely also that this method could be used with other sources of illumination, such as incandescent and combustible sources. This method utilizes only equipment that many entomologists have in their possession, namely: camera (preferably with ground glass focusing), speedlight, gray scale, projector and photoelectric light meter. Measurements are facilitated considerably by having a standardized photographic copying stand.

As indicated (Brown 1954) small opaque object photography with the speedlight (or other predictable artificial light source) can be summarized by the formula:

$$\text{(I)} \qquad d = \frac{G.N.}{(X+1)\ (f/no.)}$$

[1] Accepted for publication October 15, 1954.

where d = the lamp-(or lamps, when equidistant from subject)-to-subject distance in centimeters; G.N. = guide number of the speedlight for use in centimeters; X = the linear magnification or image length divided by subject length; and f/no. = f/number, f/stop or relative aperture as marked or engraved on the lens mount. It will be noted that the quantity (X+1) (f/no.) is the effective aperture.[2] Examining formula (I) it is evident that all quantities can be readily measured, calculated or adjusted with the exception of the guide number. So for the purposes of this paper, formula (I) can be rearranged as follows:

$$\text{(II)} \qquad \text{G.N.} = (\text{d})\ (\text{X}+1)\ (\text{f/no.}).$$

In essence then this paper describes a method of determining the guide number of the speedlight. This is necessary, as has been indicated (Brown 1954) and as will be shown later in this paper, in that the guide number of some speedlights is not constant in low power photomicrography in contrast to the situation in conventional photography.

For this method it is necessary to have two standard subjects or objects for photographing which will not change and for the first of these a gray scale serves very well. A gray scale is a flat strip of photographic paper which is black at one end with very dark gray as the next sharply defined area and so on to a very light gray area and finally a white area at the opposite end. A gray scale is commonly available at photographic dealers, usually in an inexpensive kit for making color separation negatives. The main advantage of using the gray scale is that the normal human eye can readily detect small differences in shades of gray; such differences can result from relatively small differences in amounts of illumination. Of course the gray scale film images can be used in conjunction with a densitometer in which case an entirely objective determination is possible.

Suppose several exposures are made of a gray scale with the speedlight on a color reversal film under constant conditions and the only variable being various f/stops. When the film is returned from the processor these transparencies are projected in a conventional projector onto a white matte-surfaced screen so that the projected image of the gray scale is of the same dimensions as the actual gray scale. By holding the gray scale next to its image, and in a clear portion of the beam of light, those transparencies that are under- or over-exposed are quickly determined. Under-exposure is indicated in the film image by the black end and the first stage of dark gray of the gray scale, both appearing black; over-exposure is indicated by the white end and first stage of light gray, both appearing white. Proper exposure is indicated by an exact duplication of the gray scale, that is, as exact as color film can record.

Now suppose, under the same conditions (same magnification, etc.) that proper exposure was obtained above with the gray scale, another exposure is made but this time a smooth-surfaced white posterboard or cardboard (which can be called the standard white subject) is used as the subject. This uniform standard white subject is large enough so that it will be the only thing recorded on film at any desired magnification. After this color transparency (which can be called the standard slide) is processed, it is projected onto a white matte-surfaced screen and the reflected light is measured with a photoelectric exposure meter.

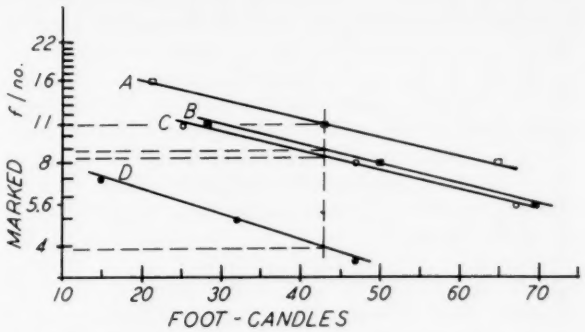


FIG. 1.—Relationship of light transmission index of Kodachrome test transparenceis to marked f/no. at 4 magnifications with the "Thriftlite" speedlight, model AC-40, with 2 equidistant lamps and reflectors. Curve (A): 0.206× magnification, lamps at 40.0 cm.; Curve (B): 1.00× mag., lamps at 24.1 cm.; Curve (C): 0.048× mag., lamps at 63.3 cm.; and Curve (D): 4.04× mag., lamps at 21.1 cm.

The writer's set-up for light measurements included a "Golde Manumatic" 300-watt projector with the lens, of 5-inch focal length, at about 3 feet from the screen. With a slide in the projector, the length of the projected horizontal format was about 6 inches. The exposure meter used was a General Electric, model DW-48, with the hood removed so that the light units were indicated directly in foot-candles. With the meter just below the beam of light and pointed toward the center of the projected image, maximum light values were obtained with the meter at about 7 inches perpendicularly from the screen. This particular relationship of projector, light meter and screen was rigidly maintained for all light measurements.

Now, it seems logical to presume that a photograph of the standard white subject at any other magnification, and/or with any other speedlight, would have to yield a transparency with the same foot-candle reading as the standard slide to be considered properly exposed. Besides different magnifications it can be further presumed that for proper exposure, sources of illumination in addition to speedlight, such as incandescent and combustible, would have to yield transparencies of the same foot-candle reading as the standard slide with, of course, equilibration of the spectral qualities of these other sources by proper choice of color film and/or light filters.

If Kodachrome photographs of the standard white subject are taken at several magnifications and at several f/no's. within each magnification and foot-candle readings are taken of each transparency, the data can be plotted, as in the example in figure 1, on semi-logarithmic graph paper, in which foot-candle readings are related to marked f/no's. It will be noted that straight line curves are obtained. Note also that the standard slide, giving a reading of 43 foot-candles at f/11, is included in the series (curve A) at 0.206× magnification with centers of the two

[2] When using a microscope objective (other than oil immersion) alone, f/no. = (0.5)/(numerical aperture). When using microscope objective and ocular combination (Kingslake 1951), i.e., the complete microscope, effective aperture = (exit pupil-to-film distance)/(exit pupil diameter).

FIG. 2.—Relationship of guide number for centimeters to magnification for 3 brands of speedlights. Curve (A): "Strobonar V," model HR-40, single lamp and reflector; Curve (B): "Thriftlite," model AC-40, 2 lamps and reflectors; Curve (D): same as (B) but without reflectors; and Curve (C): "Speedotron," model P-200, 2 lamps and without reflectors.

speedlight lamps at 40 cm. from the center of the subject. The purpose of plotting the data, of course, is to determine by interpolation the marked f/no. at any given magnification that would produce a slide of the same light transmission as the standard slide. Substituting in formula (II), the guide number is calculated as: (40 cm.) $(0.260\times+1)(f/11)=(40)(1.206)(11)=530$. At $0.048\times$ magnification (curve C), the guide number is: $(63.3)(1.048)(8.4)=556$. Calculations for the other two magnifications (curves B and D) are similar (see caption for Fig. 1).

The foregoing calculated guide numbers can be related to magnification by plotting them on semi-logarithmic paper and connecting the points as in curve (B) in figure 2. The magnifications used were selected to give approximately equal increments on the axis of the abscissa in this graph. Of course, intermediate magnifications can be determined also for possibly increased accuracy. However, the writer feels that for his purposes sufficient accuracy was obtained by interpolating the guide number for intermediate magnifications. Curve (B) in figure 2 is for two equidistant lamps, with reflectors, of the "Thriftlite" speedlight, model AC-40, with an "Intensifier," model AD-15. Other curves are noted in figure 2; these were determined by the same method as for curve (B). Curve (D) in figure 2 refers to the same Thriftlite speedlight but without reflectors on the lamps, or with a small reflector made of $\frac{1}{2}$ of a frozen juice concentrate can over each lamp, the guide number being the same in either case (Brown 1954).

Curve (C) in figure 2 is for two equidistant lamps, without reflectors, of the "Speedotron" speedlight, model P-200. It should be noted that a speedlight that precisely obeyed the inverse square law of illumination in low power photomicrography (i.e., had a constant guide number) would give a horizontal straight line curve in figure 2; of the speedlights tested the Speedotron as used comes the nearest to this. Curve (A) in figure 2 is for a single lamp, with a non-detachable reflector, of the "Strobonar V" speedlight, model HR-40, the only speedlight of those tested that showed a consistent increase in guide number as the lamp was brought nearer the subject. Possibly this attests to the good design of this speedlight. In low power photomicrography, the increasing guide number of the Strobonar V helps to compensate for the increasing effective f/no. as magnification is increased, so that less movement of the lamp is necessary with changes of magnification (see formula I).

All tests were made with the lamps at 45 degrees from the optical axis of the lens and the subjects were on a plane perpendicular to the optical axis. The gray scale was so oriented that all parts were as near equidistant from the lamp(s) as possible. In tests with a speedlight having 2 lamps, the lamps were located on opposite sides of the optical axis. To convert a guide number for feet to a guide number for centimeters, multiply the former by 30.48, which is the number of centimeters per foot. To convert a guide number for centimeters to one for feet, divide the former by 30.48.

The foregoing method may appear unduly involved but with proper planning and in practice it is rather straightforward. For those wishing to use this method, a few suggestions may be helpful. The speedlight manufacturer usually supplies a guide number for use in feet. With the lamp (or lamps) illuminating the object at an angle of 45 degrees from the optical axis, the manufacturer's guide number should be multiplied by about $\frac{2}{3}$ to give an adjusted guide number. As a starting point, this adjusted guide number can be converted for use in centimeters, the value substituted in formula (I) to find the lamp distance and, for the purposes of the test, the guide number can be assumed to remain constant. Table 1 presents an example of a hypothetical test to be made with a speedlight with manufacturer's guide number of 45 for use in feet and with Kodachrome daylight film. If the guide number remained constant the central stop, f/8, would give correct exposure. Note that the complete test can be made at one time, using one 36-exposure roll of film and covering a range of subject lengths from about 28 inches to 1/10 inch. Half-stop intervals are represented in the series with the gray scale and in 2 cases with the other $0.20\times$ magnification. At $0.20\times$ magnification the image of a 6-inch gray scale almost fills the length of a double frame 35 mm. film as mounted for projection.

It may be found that with some of the less powerful speedlights with nondetachable reflectors, there will be a minimum lamp to-subject distance possible at the higher magnifications because of interference of the reflector

Table 1.—Example of a set of hypothetical test exposures for speedlight guide number determination in low power photomicrography using manufacturer's guide number of 45, for Kodachrome daylight film, as starting point.[a]

MAGNIFICATION	SUBJECT	LAMP(S)-TO-SUBJECT DISTANCE (CM.)	MARKED RELATIVE APERTURE (F/NO'S.)
0.05×	white standard	109	4, 5.6, 8, 11, 16
0.20×	white standard	95	4, 5.6, 6.4, 8, 9, 11, 16
0.20×	gray scale	95	4, 4.5, 5.6, 6.4, 8, 9, 11, 13, 16
1.00×	white standard	57	4, 5.6, 8, 11, 16
5.00×	white standard	19	4, 5.6, 8, 11, 16
15.00×	white standard	7.1	4, 5.6, 8, 11, 16

[a] Lamp(s) 45 degrees from optical axis.

with the extension tubes and lens. In this case the minimum distance can be measured and this value substituted in formula (I) or (II) to calculate the maximum possible magnification.

In low power photomicrography of biological subjects, some workers (Brown 1954), for rapidity of operation, use a single f/no. with a given magnification and film. It is usually desirable to obtain as much depth-of-field as possible without a loss of resolution, in the plane focused upon, from the effects of diffraction. For given magnifications, films, f/no's., and guide numbers, such as from a graph as in figure 2, the lamp(s)-to-subject distances can be calculated, arranged in tabular form, and speedlight calibration can be happily forgotten. Low power photomicrography by reflected light then becomes a routine and predictable operation making possible uniformly exposed photographs for publication and conventional projection.

SUMMARY.—A method is described for calibrating any speedlight for use in photography of small, opaque objects, such as insects. In essence this involves determination of the guide number of the speedlight. Correct exposure at one magnification is first determined by taking several photographs of a gray scale and comparing by projection the color reversal film images with the gray scale. Then at the same settings for correct exposure with the gray scale, another photograph is made of a uniform white card. An index of the light transmission of this standard photographic slide is determined by projecting it on a white screen and measuring the reflected light with a photoelectric exposure meter. The assumption is then made that a photograph of the white card at any other magnification, and/or with any other speedlight, would have to yield a transparency of the same light transmission index as the standard slide to be considered properly exposed. After taking several photographs of the white card at other magnifications, and with other speedlights, the light transmission of these photographs can be plotted, compared with that of the standard slide, and the guide numbers calculated. The guide numbers can be plotted in relation to magnification so that, for any magnification, lamp-to-subject distance for proper exposure can be quickly determined. Such guide number curves are presented for three commonly available speedlights: the Strobonar V, the Thriftlite AC-40 and the Speedotron P-200.

REFERENCES CITED

Brown, L. R. 1954. A standardized laboratory apparatus for using the speedlight in photography of insects and other small objects. Lepidopterists' News **7**: (5 & 6): 148–66.

Clark, Walter. 1952. Experimental low-cost, short-run color printing. Penrose Annual **46**: 125–7.

Kingslake, Rudolf. 1951. Lenses in photography. Garden City Books, Garden City, N. Y.

Comparative Toxicity of Certain Acaricides to the Carmine and Green Forms of the Two-Spotted Spider Mite[1]

CHARLES E. COLE and F. W. FISK,[2] *Department of Zoology and Entomology, The Ohio State University, Columbus*

The two-spotted spider mite, *Tetranychus bimaculatus* Harvey, is common to most areas of North America where it occurs as either a carmine or as a green color form. Both color forms may be found in the southern United States where the carmine form predominates (McGregor & McDonough 1917); however, in the northern United States, while the green color form is widespread, the carmine form is restricted to greenhouses or comparable situations.

Since both color forms are being used in the evaluation of chemical compounds for acaricidal potentiality, a determination of their relative susceptibilities to some commonly employed acaricides seemed advisable. If, for instance, the two forms proved to be equally susceptible to the acaricides tested, then one might predict that they would respond similarly in future tests.

The red, or carmine, form used in this work was obtained from the Beltsville, Maryland colony through the courtesy of Dr. Floyd F. Smith, Bureau of Entomology and Plant Quarantine, United States Department of Agriculture. Identification of specimens from this colony were verified by Dr. Edward A. Baker, United States Department of Agriculture and Dr. A. Earl Pritchard, University of California as being typically *T. bimaculatus* Harvey. The green phase had previously been identified by Dr. E. A. McGregor as the same species.

MATERIALS AND METHODS.—The mites to be tested were reared separately in isolated rooms of our Entomology Greenhouse. Both colonies were maintained throughout the experimental work on red kidney bean plants. An additional colony of the carmine form was also reared on Blue Hubbard Squash for the host difference tests.

Commercial formulations of the acaricides used were as follows: TEPP 40%, EPN 27% W.P., malathion tech., DMC 25% Emuls. Conc., Aramite 15% W.P. The malathion was made up as a 25 per cent emulsifiable stock concentrate. The dilute aqueous dispersions used in the tests were prepared as needed from the above formulations.

Individually potted red kidney bean plants were infested by placing a trifoliate leaf from the stock colony onto each primary leaf to be treated. These plants were then treated by immersing or dipping the infested leaves into an aqueous suspension, emulsion, or solution of the toxic material, or by applying a spray. The laboratory spray method made use of a modified DeVilbiss Spray Booth as shown in figure 3. The mites were not counted before testing but mortality counts were made at 24, 48, or 72 hours following treatment, depending on the

[1] Accepted for publication October 18, 1954.

[2] Acknowledgment is due Samuel S. Ristich and William L. Butts, Ohio State Research Foundation Project 116-A, for their suggestions and aid in the development of the leaf-cutting device.

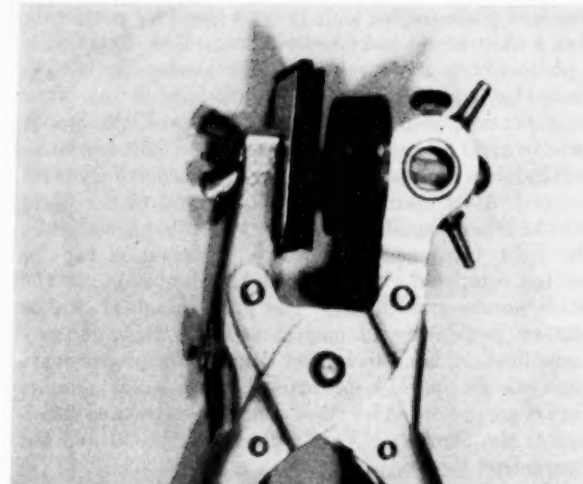


FIG. 1.—Mechanical leaf-cutting device constructed from leather punch.

type of acaricide used. The total number of mites per leaf was found to range from 29 to 87 with the average being 51.

The primary leaves of red kidney bean plants are quite large and are convoluted at their margins. The two-spotted spider mites soon spin a web across such convoluted areas and so form a barrier through which the applied materials must penetrate. Also, since mites accumulate at the convoluted areas of the bean leaf, it was difficult to evaluate mortality as the convolutions fold under when placed in the counting frame, a hinged device covered with a glass plate marked off in $\frac{3}{8}$-inch squares. Considering the above factors, a smaller leaf with a fairly flat outer margin seemed desirable. To accomplish this, mechanical leather punching pliers were transformed into a punch (Figure 1) designed to cut $1\frac{1}{2}$-inch diameter circles without severing the leaf from the bean plant (Figure 2). No obvious damage to the punched leaf circles was noted. Since each leaf remained attached to its petiole it resisted wilting for as long as an uncut leaf.

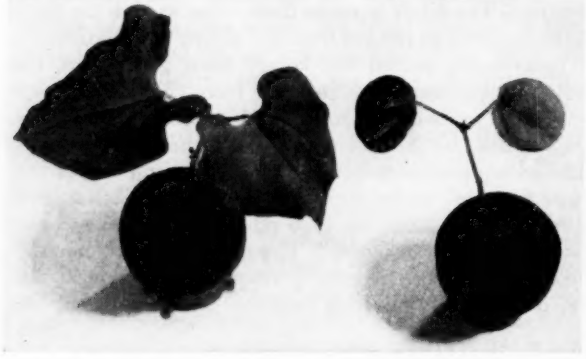


FIG. 2.—Potted bean plants. At left with uncut leaves. At right with leaves cut to $1\frac{1}{2}$ inch circles.

From four to eight single leaf replicates (two to four plants for each color form) were used for each concentration of chemical tested. Each color form was treated on separate plants. The per cent mortality for each test was computed on the basis of the total number of mites for each concentration, rather than by averaging individual replicates. Abbott's formula was employed for any tests in which the control mortality was in excess of five per cent. Two or more complete tests (on different days) were run for each chemical. For each chemical and test the significance of the differences noted between the two color forms was tested using the ranking method of Wilcoxon (1949) for groups of replicates.

RESULTS AND DISCUSSION.—The results of the toxicity tests are summarized in the LD_{50} and LD_{90} values in table 1. It will be noted that where both spray and dip methods were employed that spraying required the larger dosages.

Using Wilcoxon's ranking method to evaluate the results, no significant difference between the two color forms was found in any of the eight tests with DMC, the six tests with Aramite, or the three tests with TEPP. The results of three tests with EPN indicated a significant difference at the five per cent level of probability, the green form being more susceptible. Just the reverse was found when the tests with malathion were analyzed;

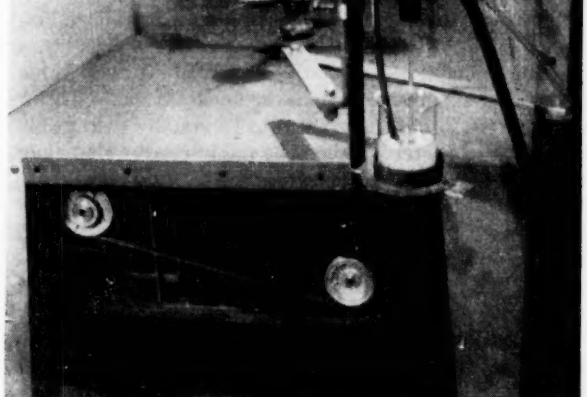


FIG. 3.—The Modified DeVilbiss Spray Booth.

the red form proved more susceptible at the two per cent level of probability.

Only one direct reference to a toxicological comparison of these two color forms could be found in the literature. Neiswander *et al.* (1950) reported that, when the two color forms had been established 3 weeks on bean plants, there was no significant difference in mortality due to applications of three acaricides of undisclosed composition, although initially the red form was more susceptible. In another test when the red form was taken from beans and the green form from roses, systemic applications of selenium to roses produced a significantly higher percentage kill of the red form. This difference in susceptibility was attributed to host plant differences. Yet after about 4 months on selenium-treated roses the red form became more like the green population, both in susceptibility and appearance. Those workers also noted that mites established on tomatoes were more susceptible than those on beans or roses.

In order to secure some additional data on the effect of different host plants on the susceptibility to two additional toxicants a population of red form mites was established on Blue Hubbard Squash for over a month. Mites from this population were transferred to red kidney bean leaf circles and tested in comparison with red form mites reared on bean. With malathion as the test chemical no significant differences between the two populations were found, the results in both cases closely agreeing with the values for malathion against the carmine form in table 1. With DMC however, the carmine mites reared on squash were found to be less susceptible than those reared on bean. The difference was calculated to be significant at the two per cent level of probability. These results indicate that differences in mite susceptibility may sometimes result from different host plants, but certainly they cannot be predicted.

SUMMARY AND CONCLUSIONS.—There are two basic color forms of *Tetranychus bimaculatus* Harvey, a carmine phase and a green, two-spotted phase. Since both color forms are employed in the evaluation of chemical compounds of acaricidal potentiality, laboratory dip and spray tests were conducted to determine their relative susceptibilities to five acaricides. The results are summarized in a table of LD_{50} and LD_{90} values.

A new device was contrived to trim primary bean leaves to 1½-inch circles, without severing the leaves from the bean plant petiole. Many advantages are derived when cut leaves of a standard size are used for mite tests.

Table 1.—LD_{50} and LD_{90} values, in parts per million, for five acaricides used against the red and the green color forms of *Tetranychus bimaculatus* Harvey.

ACARICIDE	NO. OF TESTS	METHOD OF TEST	TIME OF MORTALITY COUNT, HRS.	LD_{50}		LD_{90}	
				Red	Green	Red	Green
TEPP	3	dip	24	3.8	2.5	13.0	17.0
EPN	3	dip	24	5.5[a]	3.9[a]	20.0	12.0
Malathion	2	dip	48	36.0[b]	48.0[b]	96.0	120.0
DMC	1	dip	24	9.6	6.8	26.5	20.0
DMC	3	dip	48	8.0	6.0	28.5	19.0
DMC	1	dip	72	7.9	4.0	17.5	12.0
DMC	3	spray	48	31.0	26.0	78.0	60.0
Aramite	3	dip	48	2.9	2.9	18.0	19.5
Aramite	3	spray	48	22.0	14.0	93.0	72.0

[a] Significantly different at the 5% level.
[b] Significantly different at the 2% level. No significant differences between the color forms in other tests.

No significant difference between the two color forms was found in both spray and immersion tests with Aramite, DMC, and TEPP. The green form tended to be more susceptible to EPN, at the five per cent level, and less susceptible to malathion, at the two per cent level of probability. A red form population from squash when tested on bean in comparison with the red form from bean was less susceptible to DMC, but equally susceptible to malathion.

On the basis of this study and the work of Neiswander *et al.* the authors conclude that the relative susceptibilities to color forms of *T. bimaculatus* to different acaricides may or may not differ, depending on the acaricide, and that these responses may or may not be further mediated by host plant differences. Although the differences, when present, are not nearly so great as would be noted in insecticide resistance studies, they cannot be predicted nor should they be overlooked in quantitative evaluation work.

REFERENCES CITED

Abbott, W. S. 1925. A method of computing the effectiveness of an insecticide. Jour. Econ. Ent. **18:** 265–7.

Jeffers, W. A., and S. S. Ristich. A simple, versatile spray apparatus for evaluating insecticides. Unpublished. Dept. of Zoology and Entomology, The Ohio State University.

McGregor, E. A., and F. L. McDonough. 1917. The red spider on cotton. U. S. Dept. Agr. Bull. **416:** 1–72.

Neiswander, C. R., J. G. Rodriguez, and R. B. Neiswander. 1950. Natural and induced variations in two-spotted spider mite populations. Jour. Econ. Ent. **43:** 633–6.

Wilcoxon, Frank. Rev. 1949. Some rapid approximate statistical procedures, (16 pp. booklet) American Cyanamid Company, New York, N. Y.

CORRECTION FOR VOLUME 47: 1118–9

To indicate to the reader that winged and not wingless aphids were found on potato plants the (A) should be added to *Solanum tuberosum* for the following species of aphids:

Amphorophora nervata (Gill)
Amphorophora sonchi (Oestl.)
Aphis bakeri Cowen
Brevicoryne brassicae (L.)
Capitophorus braggii (Gill)
Capitophorus xanthii (Oestl.)
Hyalopterus arundinis (Fabr.)
Macrosiphum dirhodum (Walk.)
Macrosiphum granarium (Kirby)
Mindarus abietinus Koch.
Myzocallis robiniae (Gill)

Parathion Residues on Celery[1]

C. H. Van Middelem[2] and J. W. Wilson[3,4]

There has been considerable work done on the residues of parathion on fruits, vegetables and forage crops during the past 5 years. However, most of the reported investigations are from areas far removed from the South and often on crops of no great importance to this region. Because Florida celery is grown under climatic and cultural conditions somewhat different from other areas, an extensive study on accumulative effect of repeated weekly applications of parathion would be desirable. Since the insect problem is more acute here, heavier dosages of insecticides are necessary. Therefore, a somewhat higher residue could be anticipated at the termination of a particular spray program. The only published data concerning parathion residues on this crop reviewed by the authors was the docket presented to the United States Food and Drug Administration by the American Cyanamid Company (1949), and some studies in Massachusetts by Whitcomb (1953) who reported that celery leaves collected 20 and 27 days after treatments had 4.6 and 0.8 ppm respectively of parathion residue.

The general consensus of opinion is that parathion residues break down very rapidly due to their inherent volatility. Disappearance by normal weathering processes and by dilution can be important factors also, especially with rapidly growing plants as indicated by Sloan *et al.* (1951) and Hopkins *et al.* (1952).

Ginsberg *et al.* (1949, 1950) found no apparent translocation of parathion from dusts, sprays or soil treatment in onions, peas, turnips, corn stalks or potato tubers. The internal as well as the external residues in the edible portions of cauliflower were found to be practically nil by Kasting & Harcourt (1952). No evidence of translocation of parathion was noticed by Birk & Oughton (1952) in swede turnips even after two very heavy field applications.

Working on apples and peaches, Fahey *et al.* (1952) concluded that, in the absence of rainfall and during a period of relatively uniform temperature, the loss of parathion from residue deposits is a function of the log of the time elapsed. Recently Bobb (1954) reported that residual effectiveness of parathion on the peach leaves was less than 1 week, but on the peach tree bark the insecticide was effective almost 4 weeks.

Under greenhouse conditions with tomatoes and cucumbers, Smith *et al.* (1952) reported that parathion residues did not accumulate with repeated applications at biweekly intervals. This group also noted that the initial residues were higher on immature lettuce than on the mature plants. This was due to the fact that the immature plants covered the same surface area but weighed only one quarter as much.

When parathion first appeared in Florida in 1947, farmers were told to observe an interval of 3 to 4 weeks between the last application and harvest time, in order to safeguard the consumer. During the past few years, additional information and experience has resulted in this weathering period being reduced unofficially to 15 days by the Experiment Station. The present study was initiated in order to establish a realistic period which a Florida farmer should wait before harvesting, even after repeated weekly applications throughout the growing season.

The purpose of this study was to determine the concentration of parathion residues remaining on mature celery at harvest time. An endeavor was made to apply as much or more insecticide than even the most enthusiastic farmer might utilize throughout the growing season. It should be remembered that celery from these experiments was unwashed. If the celery has been processed through the commercial packing houses, the reported residues would undoubtedly have been considerably lower.

Materials and Methods.—Parathion was applied on Pascal celery in plots 40 feet long, 4 rows wide, 30 inches apart. The power sprayer, operating at a pressure of 200 pounds per square inch, had five cone-type nozzles per row located as follows: One nozzle directly over the row, one at each side above and directed downward at an angle of 45 degrees from the horizontal and two more nozzles located one on each side of the row parallel to the ground and about 8 inches from the ground level. By the use of this equipment and at the speed the tractor was driven, approximately 90 gallons of spray per acre were applied.

In 1953, the field experiment was composed of six treatments plus a check randomized in blocks and replicated six times. Three treatments were subjected to 1½ pounds per acre per application of 15 per cent wettable powder and the other three received a liquid concentrate containing 4 pounds of technical parathion per gallon at the rate of ½ pint per acre per application. During the 1954 season, only three treatments of 15 per cent wettable powder plus a check were run on a field experiment which was replicated four times. The same size plots and spray equipment were used the second year.

Since so little parathion was reported in the literature as being translocated within the plant, it was decided to analyze only for surface residues on celery in this investigation. Even though a very small percentage of the total residue probably reached subsurface areas, the resultant fine chopping of the entire plant before the benzene extraction should have insured the dissolving of practically all the insecticide in the benzene.

Ten mature celery plants were cut at random within each plot. The plants were field trimmed and immediately brought to the laboratory for cutting and extraction. Here the samples were divided into foliage and stalk portions. Each plant portion was cut finely and placed in a rotary drum and thoroughly mixed. A 1000-gram sample was randomly chosen and placed in wide-mouthed gallon glass jars with 1000 ml. of benzene. The jars were sealed

[1] Florida Agricultural Experiment Station Journal Series, No. 291. Accepted for publication October 20, 1954.

[2] Assistant Biochemist, Fla. Agr. Exp. Sta., Gainesville.

[3] Entomologist, Fla. Agr. Exp. Sta., Central Florida Experiment Station, Sanford.

[4] The writers express their appreciation to Dr. R. E. Waites, Fla. Agr. Exp. Sta., for his generous assistance in harvesting and extraction of the plant material.

Table 1.—Parathion residues on celery (P. P. M.)

Treatment Number[a]	Number of Applications	Time Interval	Foliage Range	Foliage Average	Stalk Range	Stalk Average
1. Wet. Powder	16	4 hrs.	1.90–2.82	2.33	1.05–1.35	1.19
4. Liquid Conc.	16	4 hrs.	1.50–1.90	1.69	0.85–1.25	1.04
2. Wet. Powder	12	7 days	0.55–1.65	1.05	0.35–0.70	0.49
5. Liquid Conc.	12	7 days	0.62–1.20	0.85	0.35–0.70	0.48
2. Wet. Powder	12	14 days	1.05–1.47	1.22	0.65–0.90	0.76
5. Liquid Conc.	12	14 days	0.95–1.08	1.01	0.45–0.70	0.59
3. Wet. Powder	8	7 days	0.55–1.30	0.87	0.18–0.40	0.25
6. Liquid Conc.	8	7 days	0.38–0.70	0.59	0.13–0.35	0.22
3. Wet. Powder	8	14 days	0.50–0.77	0.61	0.17–0.55	0.37
6. Liquid Conc.	8	14 days	0.34–0.54	0.44	0.12–0.35	0.22
3. Wet. Powder	8	28 days	0.60–0.90	0.75	0.50–0.65	0.58
6. Liquid Conc.	8	28 days	0.55–0.68	0.61	0.40–0.52	0.47

[a] Treatment No. 1, 2, 3 received 1.5 lbs./Acre 15% Wettable Powder; treatment No. 4, 5, 6 received 0.5 pt./Acre 50% liquid concentrate.
[b] Time lapse from last application until harvest. Harvest dates: March 11, 25, April 1, 1953.

using several layers of cellophane to protect the rubber liner and then placed for 30 minutes on a tumbling machine equipped with horizontal rollers. After extraction, duplicate 250-ml. aliquots of filtrate were saved for chemical analysis. Samples were stored in sealed pint jars at 40° F. until analyzed.

All subsequent data are reported in parts per million (ppm) calculated as milligrams of parathion per kilogram of fresh plant material. The analytical procedure used was that proposed originally by Averell & Norris (1948) and later modified by Gunther & Blinn (1950). Before the actual analysis was begun, all samples had to be decolorized using a mixture composed of nuchar, filter-cel, sodium sulfate, attaclay and hyflo-supercel. After decolorizing, a known quantity (usually 200 ml.) of clear benzene filtrate containing the parathion was measured out into 300-ml ground glass Erlenmeyer flasks and placed on an electric six-unit extraction apparatus. The flasks were then attached to Friedrich condensers and heat applied gently until all the benzene except approximately 20 to 30 ml. had been distilled over. Great care was taken so that the distillation was not carried too long resulting in all the solvent being carried over and considerable parathion lost. By using these special condensers, the sample is rapidly reduced to a workable volume and simultaneously, 80 to 90 per cent of the expensive solvent is recovered for future use instead of being lost through ordinary evaporation.

RESULTS.—In 1953, the following treatments were replicated six times. All figures shown in table 1 are averages of duplicate analyses conducted on samples taken from six field replications.

Table 2.—Rainfall and average monthly temperatures[a] in Sanford, Florida, during the course of the 1953 Spraying Schedule.

Month	Rainfall (Inches)	Temperature (° F.)
December (17–31)	0.13	57.1
January (1–31)	2.89	59.6
February (1–28)	2.97	62.9
March (1–31)	5.87	68.6
Jan, Feb, March Total—	11.73	

[a] Each day temperature calculated as the mean of 24-hour period.

Table 3.—Parathion residues (P. P. M.)

Plant Portion	No. of Weekly Applications[a]	Range (4 Replications)	Average
	Harvest A[b] *(4 hours after last application)*		
Foliage	15	4.56–6.22	5.93
	12	4.30–6.00	5.37
	9	4.10–6.31	5.25
Stalk	15	0.54–0.79	0.64
	12	0.44–0.68	0.55
	9	0.40–0.69	0.55
	Harvest B[c] *(7 days after last application)*		
Foliage	15	0.82–1.35	1.05
	12	0.76–1.18	0.96
	9	0.71–1.09	0.87
Stalk	15	0.16–0.26	0.21
	12	0.14–0.20	0.17
	9	0.10–0.21	0.15

[a] Used 1.5 pounds of wettable powder, 15%, per acre. No significant differences between these treatments.
[b] March 17, 1954.
[c] March 24, 1954.

Results in table 1 indicate that there is a slightly higher residue from wettable powder than from the liquid concentrate formulation for all treatments. In comparing the treatments that received 8 versus 12 weekly applications a very moderate build-up of residues is noted in the treatments that received the higher number of applications. This was apparent in both the stalk and foliage samples taken 7 and 14 days after the last application of each series.

The very low residues found in the celery harvested 4 hours following the completion of 16 weekly applications in 1953 may be partially explained by a very heavy rain in the latter part of March and the relatively high mean temperature during the last month of spraying as indicated in table 2.

There must have been some parathion from treatment numbers 1, 2, 4 or 5 that drifted over on treatment numbers 3 and 6 before the last harvest (28 days after the 8th application). This might explain why the residue was slightly higher than from samples taken 14 days earlier. The same explanation may be given in the case of treatment numbers 2 and 5 where residues were also somewhat higher 14 days after the last application than they were only 7 days after. A study of table 1 indicates that there is very little cumulative effect resulting from the repeated weekly applications.

In 1954, only two harvests were made, 4 hours after the

Table 4.—Rainfall and average monthly temperatures[a] during the spray schedule period.

Month	Rainfall (Inches)	Temperature (° F.)
December (7–31)	3.10	59.0
January (1–31)	1.32	61.9
February (1–28)	0.99	61.7
March (1–24)	1.70	58.7
(Jan, Feb, March) Total	4.11	

[a] Calculated from daily mean temperatures.

last application and another 7 days later. The various spray schedules were staggered in order that all treatments would terminate simultaneously. This procedure greatly eased the harvesting problems over the previous year without sacrificing any of the necessary information required.

The results of the 1954 experiment are summarized in table 3. All figures are averages of duplicate analyses. The treatments were replicated four times.

A comparison of the 1953 and 1954 data will clearly show a considerably higher average residue for all treatments in 1954. However, if one compares the rainfall and temperature data in tables 2 and 4, it is not difficult to see why the residues were higher in the second year. The rainfall in 1953 was almost three times as great in January, February and March as it was in 1954 during the same period. Moreover, the March 1953 mean temperature was 10 degrees higher than the last 3 weeks of the 1954 growing season. These two factors taken cumulatively could very well have resulted in considerably more weathering and volatilization in 1953 than in 1954. However, in spite of the fact that in 1954 conditions were favorable for retention of maximum parathion residues, there appeared to be very little build-up between treatment schedules 15, 12 and 9. Statistical analysis showed no significant differences between these treatments.

SUMMARY AND CONCLUSIONS.—Chemical analyses of parathion were made on celery sprayed weekly for 2, 3 and 4 months to determine the amount of toxicant residues remaining on the crop at harvest time. The plants were grown in randomized plots composed of six field replications in 1953 and four in 1954. Half of the 1953 experiment (three treatments) and all of the 1954 received a uniform application of 1.5 lbs. parathion per acre per 100 gallons of 15 per cent wettable powder on each application date. The other three treatments in 1953 received 0.5 pints per acre per 100 gallons of a 50 per cent liquid concentrate per application. Samples were composed of 10 mature plants selected at random within the plot. Stalk and foliage portions of the plant were separated, chopped finely and extracted.

Parathion residues in 1953 on celery foliage were as follows: 7 and 14 days after the 8th application, 0.87 and 0.61 p.p.m., respectively; 7 and 14 days after the 12th application, 1.05 and 1.22 p.p.m., respectively, and 4 hours after the 16th application, 2.33 p.p.m. The very low residues in 1953 may be explained partially by the relatively high mean temperatures and abnormally heavy rainfall during the latter part of the spray schedule and harvesting period.

Similar treatments in 1954 resulted in the foliage samples having the following parathion residues: 4 hours after the last application, the 15, 12 and 9 weekly series resulted in 5.93, 5.37 and 5.25 p.p.m. respectively. Samples taken 7 days after application from the 15, 12 and 9 weekly series contained, respectively, 1.05, 0.96 and 0.87 p.p.m. parathion. In 1954, the rainfall in March was slightly below average; moreover, the mean temperature during the last 2 weeks of the spray schedule was 10 degrees below the mean for the same period of 1953. In spite of the fact that the 1954 residues were considerably higher than the previous year, there appears to be little evidence of accumulation even after 15 consecutive weekly applications.

It may be concluded from the data obtained that by applying the recommended dosages during weekly applications of parathion and allowing a 7-day weathering period, that unwashed celery can be sent to market from Florida with residues below 2 p.p.m.

REFERENCES CITED

American Cyanamid Company. 1949. Parathion Data Presented to U. S. Food and Drug Administration. In the matter of: Tolerance for poisonous or deleterious residues on or in fresh fruits and vegetables. Docket No. **FDC-57**: 67–68.

Averell, P. R., and M. V. Norris. 1948. Estimation of small amounts of 0,0-diethyl 0, p-nitrophenyl thiophosphate. Analyt. Chem. **20**(8): 753.

Birk, L. A., and J. G. Oughton. 1952. Parathion residues on swede turnips. Sci. Agr. **32**(1): 52–6.

Bobb, M. L. 1954. Parathion residues on peach bark and foliage. Jour. Econ. Ent. **47**(1): 190–1.

Fahey, J. E., D. W. Hamilton and R. W. Rings. 1952. Longevity of parathion and related insecticides in spray residues. Jour. Econ. Ent. **45**(5): 700–3.

Ginsberg, J. M., R. S. Filmer, J. P. Reed and A. R. Paterson. 1949. Recovery of parathion, DDT and certain analogs of dichlorodiphenyl dichloroethane from treated crops. Jour. Econ. Ent. **42**(4): 602–11.

Ginsberg, J. M., R. S. Filmer and J. P. Reed. 1950. Longevity of parathion, DDT, and dichlorodiphenyl dichloroethane residues on field and vegetable crops. Jour. Econ. Ent. **43**(1): 90–4.

Gunther, F. A., and R. C. Blinn. Mass Production Techniques for Estimating Parathion Residues. 1950. Advn. Chem. Ser. **1**: 72-7.

Hopkins, L., L. B. Norton and G. G. Gyrisco. 1952. Persistence of insecticide residues on forage crops. Jour. Econ. Ent. **45**(2): 213–8.

Kasting, P., and D. G. Harcourt. 1952. Parathion residues of cauliflower heads after spraying. Sci. Agr. **32**(6): 299–303.

Sloan, M. J., W. A. Rawlins and L. B. Norton. 1951. Factors affecting the loss of DDT and parathion residues on lettuce. Jour. Econ. Ent. **44**(5): 701–9.

Smith, F. F., F. I. Edwards, P. Giang and R. A. Fulton. 1952. Residues of organic phosphorus compounds and DDT on greenhouse vegetables. Jour. Econ. Ent. **45**(4): 703–7.

Whitcomb, W. D., 1952. The biology and control of lygus campestris L. on celery. Mass. Agr. Exp. Sta. Bull. **473.**

European Corn Borer Parasite Complex Near East Hartford, Connecticut[1]

K. D. Arbuthnot, *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*

The early history of exotic parasites of the European corn borer, *Pyrausta nubilalis* Hbn., at a study point at East Hartford, Conn., has been discussed by Baker *et al.* (1949). In a continuation of these studies since 1939 some interesting developments in the parasite complex have been observed.

A polar-coordinate scheme of sampling, as discussed by Baker *et al.* (1949) was used in describing the locations from which samples were taken in all observations on the summer, or first, and the fall, or overwintering, broods of the host from 1934 through 1941. From 1942 to 1951 a rectangular-coordinate system of 10-mile-square sections was used in the fall. The distance between sampling points and the number of insect forms per sample varied in the studies through 1942, but beginning in the fall of 1943 the same pattern was followed annually. Maps were marked to show where samples were taken in the earlier years and the data for all years were assembled in the pattern of the standard polar-coordinate sample. The standard sample included a circle 2 miles in diameter surrounded by two concentric circles 2 miles apart, the inner one divided into eight and the outer into 16 equal-sized sections for summer observations. The release point was at the center of the inner circle. The sampled area included approximately 78 square miles. Fall observations starting in 1943 were made in four 10-mile-square sections centered at the release site, and thus the sample taken near the center of each section fell near the perimeter of the area included in previous years' fall and summer sampling.

Parasite releases in Connecticut are recorded in the previous publication (Baker *et al.* 1949). No parasites were released after 1940.

The ichneumonid *Horogenes punctorius* (Roman), and the larvaevorid, *Lydella stabulans grisescens* R. & D., were established in the area before 1939. Two braconids became established later, *Chelonus annulipes* Wesm.

Table 1.—Numbers of European corn borers and polar-coordinate section from which they were taken at East Hartford, Conn., 1939–1951.

Year	Number of Borers Observed		Number of Sections Sampled	
	Summer	Fall	Summer	Fall
1939	2,080	6,317	17	24
1940	1,661	5,117	24	19
1941	278	1,351	9	7
1842	420	476	10	8
1943	0	207	0	4
1944	1,177	200	24	4
1945	1,131	210	23	4
1946	992	215	20	4
1947	533	178	17	4
1948	1,156	154	23	4
1949	1,038	221	22	4
1950	1,072	154	22	4
1951	997	—	22	—
Total	12,535	14,800	—	—

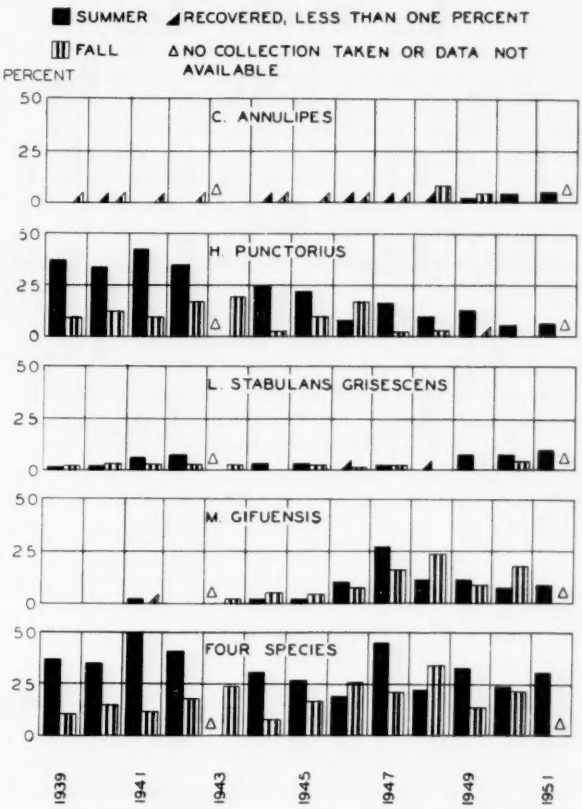


Fig. 1.—Percentages of summer- and fall-brood European corn borers parasitized by four species at East Hartford, Conn., 1939–1951.

in 1939, and *Macrocentrus gifuensis* Ashm, in 1941. The four species apparently coexisted throughout the study period, since all of them became established, although one or more of them were sometimes not recovered, probably because of inadequate numbers of hosts taken in the sampling. No other exotic species became established in this locality, and native species never accounted for as much as 1 per cent of the borers in any observation.

The numbers of hosts observed annually in the summer (first brood) and in the fall (second or hibernating brood) in the period 1939–1951 and the numbers of standard sampling sections from which they were taken are shown in table 1. The percentages of borers parasitized in each observation by each species during the same period are shown in figure 1.

Chelonus annulipes accounted for 1 per cent or less of the borers in each brood until the fall of 1948, when 8 per cent of them were parasitized. The percentages attacked were greater than one in the summers of 1949, 1950, and 1951 and in the fall of 1949. On an average 1 per cent of the summer and fall broods were parasitized by this species in the 12 years through 1950.

[1] Accepted for publication October 21, 1954.

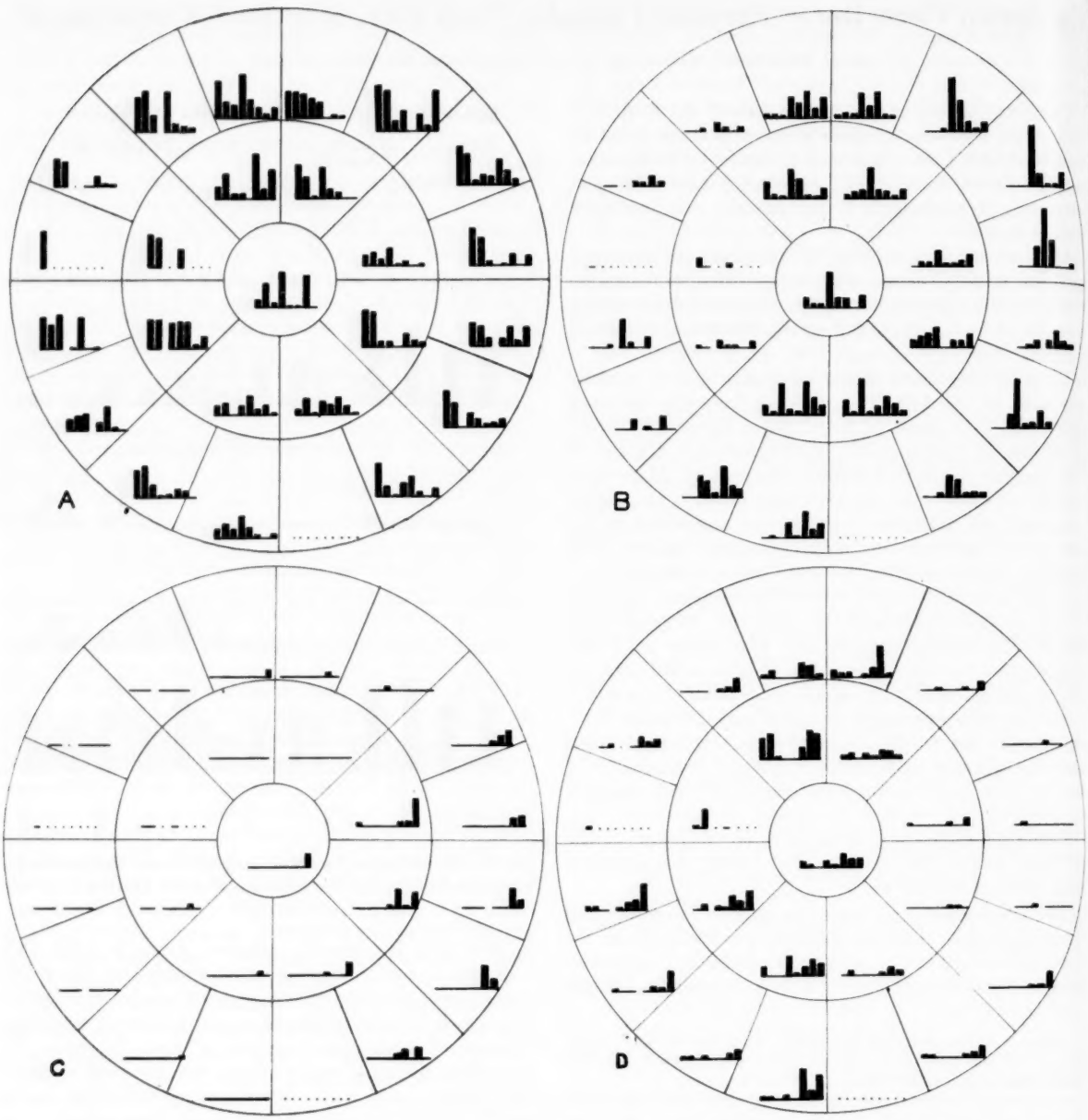


FIG. 2.—Distribution and abundance of *Horogenes punctorius* (A), *Macrocentrus gifuensis* (B), *Chelonus annulipes* (C), and *Lydella stabulans grisescens* (D), on the summer brood of the European corn borer at East Hartford, Conn. Horizontal base lines indicate the period 1944–1951 when the collections were taken, and the vertical bars show the percentage of borers parasitized in respective years reading from left to right.

Horogenes punctorius parasitized a higher percentage of summer than fall borers in 10 of the 11 years when both broods were observed, and the average percentage was over 2½ times as great in the summer (22 per cent) as in the fall (8 per cent). In the first four summers on an average 36 per cent of the borers were parasitized and in the last four only 9 per cent. Fall percentages averaged 11 in the 6-year period 1939–1944 and 5 in 1945–1951.

Lydella stabulans grisescens parasitized averages of 4 and 2 per cent in the 12 observations on the summer and fall broods. The highest parasitization in any year was 10 per cent in the summer of 1951.

Macrocentrus gifuensis parasitized an average of 7 per cent of the borers in the 12 summer and fall observations. However, the percentage in the last 6 summer and fall observations was 13.

Parasitization of the summer brood by the four species for 1939–1942 and 1944–1951 averaged 33 per cent; it was 37 per cent in 1939–1942 and 1944–1945 and 29 per cent in the last 6 years. Fall parasitization for the 12 years 1939–1950 averaged 18 per cent; in 1939–1944 it was 15 per cent and 22 per cent in 1945–1950. *Horogenes punctorius* tended to be the predominant species in the first 6 years, but *Macrocentrus gifuensis* generally pre-

dominated in the last 6. Summer parasitization by all species was higher when *punctorius* was predominant, but after *gifuensis* became the most abundant parasite fall percentages were higher than they had been previously.

After 1944 summer-brood observations were made annually in an identical manner, and data from them provided additional information on interrelations between the four species of parasites. *Horogenes punctorius* was taken in every one of the 1944 and 1945 samples, but in successive years from 1946 through 1951 it was taken in 90, 94, 83, 95, 70, and 82 per cent of the samples. *Macrocentrus gifuensis* was taken in 42, 48, 90, 100, 96, 86, 78, and 95 per cent of the samples in the successive years 1944 through 1951. The distribution of these two species and the percentages of borers parasitized by them are shown in figure 2, A and B. It is noteworthy that *punctorius* has maintained about the same percentages in the western sections, but it has declined coincident with the increase in abundance of *gifuensis* in many central and eastern sections.

The distribution of *Lydella stabulans grisescens* and *Chelonus annulipes* in the study area is shown in figure 2, C and D. *Lydella stabulans grisescens* was taken in 58, 61, 20, 35, 26, 86, 74, and 86 per cent of the respective samples in the eight successive summer-brood observations from 1944 through 1951 and *C. annulipes* in 4, 0, 5, 6, 13, 14, 43, and 45 per cent of them. *Lydella* occurred most often in the central part of the area; it was seldom taken in the eastern part. *Chelonus annulipes*, on the other hand, was taken almost exclusively in the eastern section. It was taken only three times in the western half of the area, twice in 1950 in the inner ring and once in 1951 in the outer ring. Both species have shown a wider distribution (percentage of samples producing them) and higher percentages in the area in the last 3 years of the study.

SUMMARY.—Four introduced exotic parasites of the European corn borer, *Pyrausta nubilalis* Hbn., coexisted in the vicinity of East Hartford, Conn., from 1941 to 1951. *Horogenes punctorius* (Roman) was the most abundant species until *Macrocentrus gifuensis* Ashm. became dispersed throughout the area. In most of the area at the close of this study *gifuensis* was more abundant than *punctorius*. *Lydella stabulans grisescens* R. & D. showed a wider distribution and higher percentages in 1949, 1950, and 1951 than in earlier years, but it was not generally present or abundant in the eastern portion of the area. *Chelonus annulipes* Wesm. occurred rarely in the western half of the area, was found most frequently in the sections where *L. stabulans grisescens* was seldom found, and was more abundant in the last 3 years of this study.

REFERENCES CITED

Baker, W. A., W. G. Bradley, and C. A. Clark. 1949. Biological Control of the European Corn Borer in the United States. U. S. Dept. Agr. Tech. Bull. 983.

The Inhibition of Development in the House Fly by Piperonyl Butoxide[1]

NORMAN MITLIN and MILTON S. KONECKY,[2] *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*

Piperonyl butoxide has been effectively used as a pyrethrum synergist since its synthesis was announced by Wachs (1947). Used alone in sprays it has relatively little toxicity to house flies. Gersdorff and his coworkers (1952) reported it to be one-hundredth as toxic as pyrethrins when tested against house flies by the turntable method.

In studies undertaken in this laboratory measuring the effects other than kill of chemical compounds on the house fly, *Musca domestica* L. (Konecky and Mitlin 1955), it became apparent, in initial screening tests, that piperonyl butoxide had an inhibitory effect on the development of the house fly when added to the rearing medium. Accordingly, a series of tests were set up to determine the degree of such inhibition. It was of interest, too, to determine whether flies that had developed resistance to DDT were affected similarly.

Since the action of piperonyl butoxide has been assumed to be that of lipase inhibition (Chamberlain 1950, Earle 1952), two series of tests were set up to determine whether the action could be reversed by the addition of fly lipase to the rearing medium.

PROCEDURE.—The method of testing was one developed by Mitlin *et al.* (1954) for this purpose. In series 1 each of four concentrations ranging from 0.074 to 0.25 per cent of piperonyl butoxide was incorporated in CSMA fly medium. Tests were made in duplicate. In a second and third series of tests fly lipase at varying concentrations was added to medium which had been treated with 0.25 per cent by weight of piperonyl butoxide. In a fourth series the same concentrations of piperonyl butoxide were used as in series 1, the media being inoculated with eggs from DDT-resistant flies.

The normal flies were of the 1948 NAIDM strain; the resistant flies were of the Orlando-Beltsville strain which had been selected for DDT resistance for about 150 generations. Piperonyl butoxide of technical grade was used. Fly lipase was obtained by macerating third-instar fly larvae in a Waring Blendor and removing the fat-soluble material by washing with acetone. The residue was dried in a vacuum desiccator and triturated. The resultant powder contained a very active lipase, as shown qualitatively by the litmus-milk method (Hawk *et al.* 1947).

RESULTS.—The data are given in table 1.

In series 1 all four concentrations of piperonyl butoxide caused an increase in time of larval development and a diminution of emergence.

In series 2 and 3, although fly lipase up to 0.75 per cent of the medium was added, there was no reversal of the action of piperonyl butoxide.

In series 4 piperonyl butoxide had essentially the same effect on DDT-resistant flies as on normal flies; the larval period was prolonged and emergence curtailed. However, the development of the resistant flies was inhibited to a

[1] Accepted for publication October 25, 1954.
[2] Present address: Chemistry Department, University of Illinois, Urbana, Ill.

Table 1.—Effect of piperonyl butoxide and lipase on the developmental cycle of the house fly.[a]

Concentration (Per Cent by Weight)		Mean Number of Days		Per Cent Emergence[b]
Piperonyl butoxide	Lipase	Larval Period	To Emergence	
		Series 1—Normal flies		
0.25	—	9.0	15.5	0.5
.167	—	7.5	13.5	16.0
.111	—	7.5	13.5	21.0
.074	—	7.0	12.5	61.0
Control	—	6.5	12.0	—
		Series 2—Normal flies		
0.25	—	9	—	None
.25	0.22	9	—	None
.25	.35	9	—	None
Control	—	7	12	—
		Series 3—Normal flies		
0.25	—	10	17	0.5
.25	.5	10	18	.5
.25	.75	10	17	.25
Control	—	7	13	—
		Series 4—DDT-resistant flies		
0.25	—	11.5	18	0.5
.167	—	9	18	3
.111	—	9	17	24
.074	—	9	14.5	35
—	—	7	13	—

[a] Two tests in each series.
[b] Based on control.

greater degree than that of the normal flies, for not only was the larval period longer but the percentage emergence was lower.

Throughout the study it was observed that, even though there was high larval mortality, many of the larvae pupated. The larvae in those tests appeared to be discolored and undersized. The higher concentrations of the test material caused a greater preponderance of these abnormal maggots.

Stage At Which Development Was Inhibited.—Larvae were taken at random from tests in series 3 and 4 with the higher concentrations of piperonyl butoxide, in an attempt to determine at what stage development was inhibited. All the larvae examined were found to have reached the third instar. Samples of pupae were taken each day for 9 days after pupation had begun. Very little differentiation was noted within the puparia. A few of the organisms had developed rudimentary antennae before death. The head, thorax, and abdomen could be distinguished in these pupae. In general, it appeared that death had occurred very early in the pupal stage.

Discussion.—It is evident that piperonyl butoxide, when added to the CSMA larval medium, has a highly toxic action on house flies, such action manifesting itself as a lengthening of the larval period and a reduction in emergence. Dutky and coworkers of the Entomology Research Branch (unpublished data) have demonstrated that the action is directly upon the house fly, not on the associated microbial population in the medium.

This study does not furnish any conclusive information on Earle's (1952) hypothesis that piperonyl butoxide acts as a lipase inhibitor. Although relatively high concentrations of fly lipase were used in an attempt to reverse the effect of the toxicant, they may not have been high enough to cause reversal. It is possible, too, that the action is not of the freely reversible, competitive type as Chamberlain (1950) found *in vitro*, but rather is noncompetitive *in vivo*.

No explanation can be advanced for the difference in the rates of development and emergence between normal and resistant strains of flies that were treated alike. Babers *et al.* (1953) found that under standard rearing conditions the same strains of house flies showed no differences in developmental rate. The differences found here may be due to a difference in the detoxification mechanism. It is also possible that the differences may not be significant. To determine this, a more detailed study involving a greater number of replications and a complete statistical analysis would be necessary.

It should be noted that this method of testing does not make for precise measurements. The nutritive elements in the CSMA medium may vary from lot to lot. Nor can the ingredients be mixed as uniformly as desirable. Hence, there may be rather large variations in results of tests on different populations of house flies. However, inhibition of development can be readily demonstrated by this method.

Conclusion.—Piperonyl butoxide inhibits development of the house fly when it is added to CSMA larval medium in concentrations from 0.25 to 0.074 per cent by weight. The length of larval life is directly proportional to the concentration of the chemical, and the percentage of adult emergence is inversely proportional. Death occurs in the third instar or early during pupation. Both a normal and a DDT-resistant strain of flies are affected similarly, but the effect is greater in the DDT-resistant strain. The addition of fly lipase to the larval medium in concentrations up to 0.75 per cent does not overcome the action of piperonyl butoxide.

References Cited

Babers, Frank H., John J. Pratt, Jr., and Michele Williams. 1953. Some biological variations between strains of resistant and susceptible house flies. Jour. Econ. Ent. **46**: 914–5.

Chamberlain, Roy W. 1954. An investigation on the action of piperonyl butoxide with pyrethrum. Am. Jour. Hyg. **52**(2): 153–83.

Earle, Norman W. 1952. Mode of action of piperonyl butoxide as a synergist for pyrethrum. Ph.D. Thesis, University of Illinois.

Gersdorff, W. A., R. H. Nelson, and Norman Mitlin. 1951. Relative effect of several pyrethrum synergists in fly sprays containing allethrin. Jour. Econ. Ent. **44**: 921–7.

Hawk, P. B., B. L. Oser, and W. H. Summerson. 1947. Practical physiological chemistry. 1323 pp., Blakiston Co.

Konecky, Milton S., and Norman Mitlin. 1955. Chemical impairment of development in house flies. Jour. Econ. Ent. **48**. (In press).

Mitlin, Norman, Milton S. Konecky, and P. G. Piquett. 1954. The effect of a folic acid antagonist on the house fly. Jour. Econ. Ent. **46**(5): 932.

Wachs, Herman. 1947. Synergistic insecticides. Science **105**: 530–1.

Weekly Applications of Insecticides for Control of the Pink Bollworm and the Boll Weevil[1]

R. L. McGarr, *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*[2]

In 1952 and 1953 field experiments were conducted with several organic insecticides applied at weekly instead of the usual 4- or 5-day intervals, in an effort to devise more economical and practical measures for the control of the pink bollworm, *Pectinophora gossypiella* (Saund.), and the boll weevil, *Anthonomus grandis* Boh. Experiments against both species were conducted near San Benito, Texas, in the Lower Rio Grande Valley, and also against the boll weevil near San Fernando, Tamaulipas, Mexico, in 1953. San Fernando is about 90 miles below the border from Brownsville. The results for 1952 have already been reported (Jour. Econ. Ent. 46: 1103–5). Those for 1953 are described herein.

Tests Near San Benito.—Four series of spray tests, on a total of 33 plots, were conducted with mixtures of insecticides. The treated plots ranged from 1.55 to 9.83 acres and the untreated plots from 0.62 to 2.34 acres. Three plots were given each treatment in the first three series and one plot in the fourth series.

DDT was used with endrin, methyl parathion, heptachlor, BHC, chlorthion, and a mixture of endrin and methyl parathion at the dosages shown in table 1. The lowest dosages were used early in the season when the cotton was small. The DDT was added to commercial emulsifiable concentrates of the other insecticides. In series 4 the supply of chlorthion gave out after the third application, and it was replaced with a mixture of endrin and methyl parathion. Demeton was also used in some tests.

Table 1.—Average seasonal infestations of the pink bollworm and the boll weevil and yields in large-scale spray tests near San Benito, Texas, 1953.

Treatment (Pounds per Acre)	Pink Bollworm		Boll Weevil Infestation (Per Cent)	Yield of Seed Cotton (Pounds per Acre)	
	Per cent of bolls infested	Number of larvae per boll		Total	Gain
Series 1 (average of 6.7 applications):					
Untreated	47.7	0.87	20.7	1217	
DDT 1–1.5+methyl parathion 0.25–0.375	20.1	.36	9.6	1442	225
DDT 1–1.5+endrin 0.25–0.33 +demeton 0.1 for first three applications	22.2	.36	3.9	1458	241
Series 2 (average of 6.0 applications):					
Untreated	44.3	.89	47.3	1152	
DDT 1–1.5+endrin 0.20–0.25 +methyl parathion 0.20–0.25	9.0	.13	11.6	1445	293
DDT 1–1.5+BHC 0.3–0.45 gamma	13.6	.19	30.4	1322	170
Series 3 (average of 6.0 applications):					
Untreated	32.5	.61	19.4	938	
DDT 1–1.5+endrin 0.25	17.2	.24	4.9	1072	134
Endrin 0.25+DDT 1.5 after third application	21.2	.33	4.7	1153	215
DDT 1–1.5+heptachlor 0.50	16.4	.26	5.4	1013	75
Series 4 (average of 7.0 applications):					
Untreated	62.5	1.98	31.8	170	
DDT 1–2+chlorthion 0.50[a]	35.7	.64	16.1	480	310
DDT 1–2+endrin 0.25–0.33	36.3	.70	8.8	620	450

[a] Chlorthion replaced with mixture of endrin and methyl parathion at 0.25 pound each after third application.

The applications were made with an eight-row trailer-tractor sprayer equipped with two nozzles per row and operated at a pressure of about 60 pounds per square inch so as to give approximately 5 gallons per acre.

The first application was made during the first week of blooming, when the average number of blooms infested with the pink bollworm ranged from 7.6 per cent for series 1 to 1.9 per cent for series 3. No bloom record was obtained for series 4. The applications were repeated at approximately weekly intervals until a satisfactory crop was made, except that the interval between the third and fourth applications was extended to 2 weeks, for at that time the first bolls are subject to the least damage from the pink bollworm. The longer interval was not used in series 4, as the test was started when nearby fields were about mature and large numbers of moths were moving into the treated areas.

The materials for boll weevil control were not included with the DDT in some of the tests near the end of the season, since the infestations were too low to be of importance. The endrin plot in one of the tests in series 1 was treated once with methyl parathion by mistake.

One bloom-infestation record was made for the pink bollworm in all the plots before the initial application, except for the last series.

Counts were made for the pink bollworm at approximately weekly intervals, 100 bolls being examined per plot for each record. From 4 to 6 counts were made in the different series after treatments were begun. Similar records were made for the boll weevil in all the tests where there was evidence of any appreciable injury, 100 squares usually being examined per plot for each record. Other insects did not occur in sufficient numbers to warrant the making of population records.

The seasonal infestation records for the pink bollworm and the boll weevil and the yields of seed cotton are summarized in table 1.

In series 1 both treatments gave substantial and approximately equal reductions of the pink bollworm populations, although in some of the tests not so much reduction as was desired. Boll weevils did not cause any concern except in one test. The highest gain for any test was 366 pounds for DDT plus methyl parathion and 402 pounds for DDT plus endrin. The increases in yield in this series can be largely attributed to the reduction of pink bollworms.

The mixture of DDT and endrin appeared promising against all the principal cotton pests in the Lower Rio Grande Valley, except spider mites. The DDT-methyl parathion mixture for the second year gave satisfactory control of all the major cotton insects, except the heavy

[1] Accepted for publication October 25, 1954.
[2] In cooperation with the Texas Agricultural Experiment Station. Special thanks are due Charles H. Gilbert and J. P. Goode for assistance in the field work.

Table 2.—Per cent of boll weevil infestation recorded at weekly intervals in a large-scale spray test (one plot for each treatment) at San Fernando, Tamaulipas, Mexico, 1953.

Insecticide (Pounds per Acre)	April 17[a]	April 26	May 3	May 10	May 17	May 24	May 31	June 7	Average
Untreated	3	31	47	31	59	92	99	100	65.6
Endrin 0.27–4.0	4	2	0	0	0	4	10	14	4.3
Dieldrin 0.25–0.47+ DDT 0.50–0.75+ parathion 0.125–0.25	8	3	0	1	2	3	5	16	4.3

[a] Not included in average.

populations of boll weevils after they had begun to migrate.

In series 2 both mixtures gave substantial and similar reductions of the pink bollworm populations. The mixture containing endrin and methyl parathion also gave good control of the boll weevil, whereas the DDT-BHC mixture gave only fair results. The highest gain for any test was 555 pounds for the first treatment and 340 pounds for the second. The gains in this series were from the control of both the pink bollworm and the boll weevil.

All the treatments in series 3 reduced pink bollworm populations, the reduction being least where the DDT was not included until after the third application. The boll weevil infestation was light in this series. The gains were due mostly to the reductions of the pink bollworm populations.

In series 4 both treatments gave appreciable reductions of the pink bollworm populations, but the reductions were not as much as desired. Fair to good control of the boll weevil was obtained. The increases in yield were from the control of both the pink bollworm and the boll weevil. The mixture of DDT and endrin also looked promising in this series.

Test at San Fernando.—A single large-scale test was conducted for boll weevil control in which endrin was compared with a mixture of dieldrin, DDT, and parathion. The test was not replicated. Each treated plot was approximately 13.8 acres and the untreated plot 1.29 acres. Commerical emulsifiable concentrates were used. They were applied with a tractor sprayer in about the same manner as at San Benito, except that three nozzles were used per row after the first two applications.

Eight applications were made at weekly intervals insofar as possible. Weekly infestation records were made, 100 squares being examined per plot for each record. The results, given in table 2, show that both treatments gave very good control of the boll weevil under rather severe conditions.

One record of square injury was made for bollworms that developed early as a result of a toxaphene spray applied to the entire field by the owner for boll weevil control before the test was started. The record showed 32 per cent of the squares injured in the untreated plot, 5 per cent in the endrin, and 7 per cent in the dieldrin-DDT-parathion plot. Both of the treatments gave similar satisfactory control of the bollworm. No other insects occurred in sufficient numbers to warrant the making of infestation records.

Both treatments gave similar good increases in yield of seed cotton. The gain was 1071 pounds per acre for the endrin treatment and 1021 pounds for the mixture of dieldrin, DDT, and parathion. The yield on the untreated plot was 545 pounds per acre.

Winter Mortality of the Mexican Bean Beetle in New Mexico[1]

R. L. Wallis and J. R. Douglass, *Entomology Research Branch, Agr. Res. Serv., U.S D.A.*

The investigations described in this paper were conducted from 1929 to 1935 as part of a study of the hibernation of the Mexican bean beetle, *Epilachna varivestis* Muls., in Estancia Valley, New Mexico. They were undertaken to determine the relative effects of various weather factors throughout the hibernation period on the beetles' mortality. Field studies of hibernation in large cages were supplemented by laboratory studies under controlled temperature and humidity conditions.

Field Studies.—*Procedure.*—Beetles were placed in large hibernation cages set up in the western yellow pine forest zone, which covers the higher rolling hills along the foot of the Manzano Mountains and the lower and drier slopes of the mountains. Cages were placed on both northern and southern slopes, which represent the beetles' natural hibernation quarters.

The cages were 6 feet square and 3 feet high with interchangeable tops. They had frames of 2- by 4-inch lumber covered with 14-mesh screen (Fig. 1). Two tops were provided for each cage, one of 14-mesh screen and the other of 1-mesh chicken wire to permit snow to enter but exclude animals. Extra-heavy screen was placed vertically in the soil around the base of each cage to keep out burrowing animals. When the cages were placed on the soil, care was taken to preserve the natural forest floor.

On the floor of each of two of the large cages were placed 50 sectional cages 6 by 7 inches and 3 inches deep with sides of ½-inch wood and bottoms of 14-mesh screen but no tops (Fig. 2). Each fall the sectional cages were filled with a mixture of oak leaves and pine needles,

[1] Accepted for publication October 26, 1954.

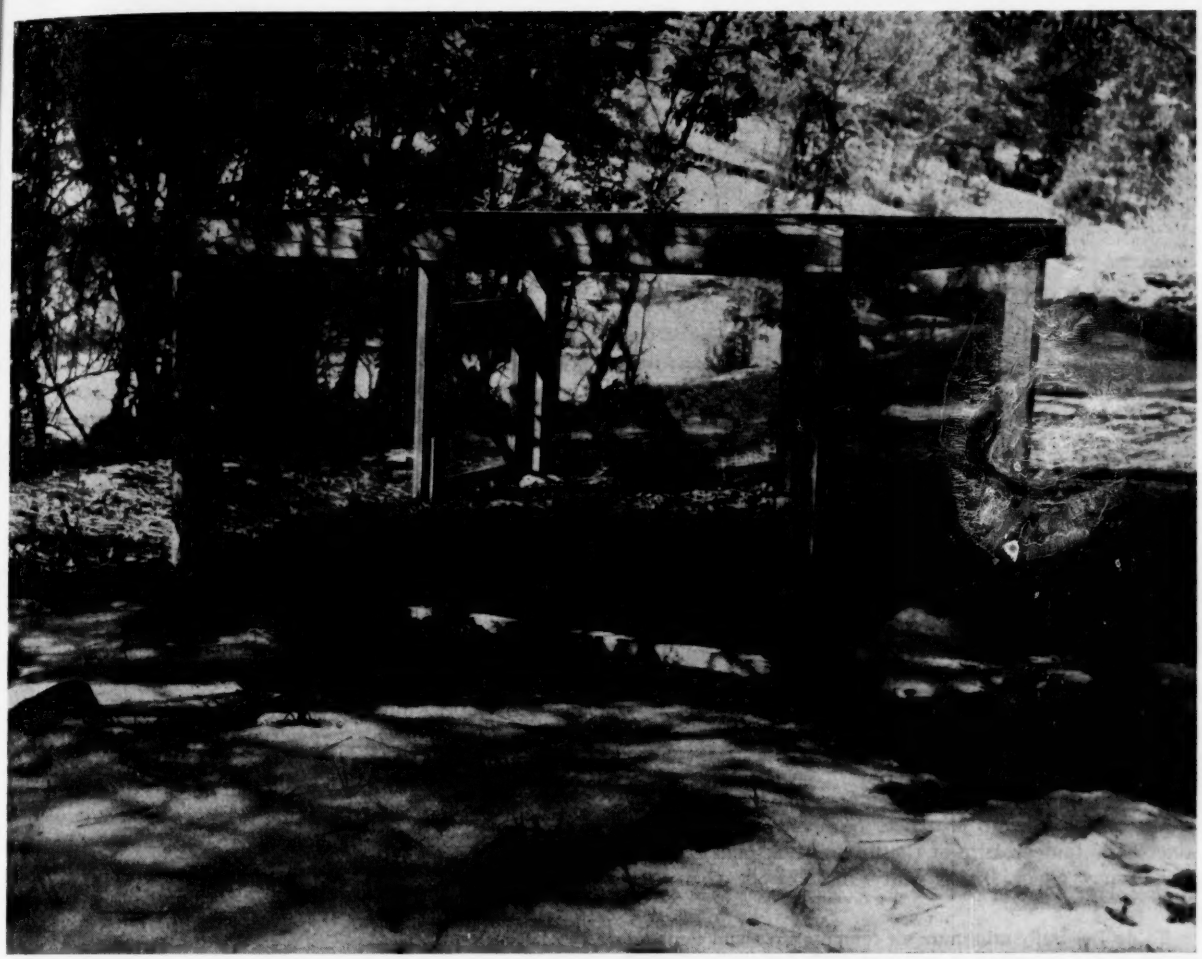


FIG. 1.—A large hibernation cage in the western yellow pine forest zone of the Manzano Mountains.

Mexican bean beetles were placed in them, and they were covered with 4 to 6 inches of the leaf mixture. The 14-mesh screen tops were left on the large cages until beetle activity ceased and then replaced with the 1-mesh wire tops until spring, when the screen was again used.

During the first 2 years 20,000 beetles were released in each large cage and allowed to enter the sectional cages at will, but this was not satisfactory. In the other years 300 beetles were placed in each sectional cage, which was then closed with 14-mesh screen, and covered with 4 to 6 inches of leaves and then 20,000 additional beetles were released in each large cage. The air temperature and the temperature of the hibernation material in each cage were recorded by thermographs.

The beetles were introduced into the cages at a time when they were naturally hunting hibernation quarters, as indicated by their flight in the fields. This time ranged in the different years from September 27 to October 16. On the 1st and 15th of each month from November or December until June or July two sectional cages were removed from each large cage and taken to the laboratory, where they were examined for live and dead beetles and the mortality was calculated.

Results.—The beetle mortalities each season on the northern and southern slopes, together with temperature and snowfall records, are shown in figure 3. The mortality percentages are 6-week moving averages.

In most seasons the mortality was slightly higher on the northern slope. The highest mortality occurred in the winter of 1933–34, when there was little snow cover to give protection and provide moisture in the hibernation material. In 1934–35 the snow fell too late to be of much protection. The mortality was highest each season at the beginning of the hibernation period and lowest at midwinter, except in those years when there was little snow cover.

The lower mortality with snow cover is explained by the differences in the temperature of the hibernation material (Table 1), which was 9° to 21° F. higher under snow cover than without snow cover. Even much colder air temperatures, if not too prolonged, may not cause very low temperatures under snow cover.

In a previous investigation Douglass (1933) found on December 19, 1927, that the temperature of the hibernation material of oak leaves and pine needles under 8 inches of snow was 21° F. as compared with an air temperature of minus 21°. Again on February 10, 1929, he found a temperature of 25° in hibernation material under

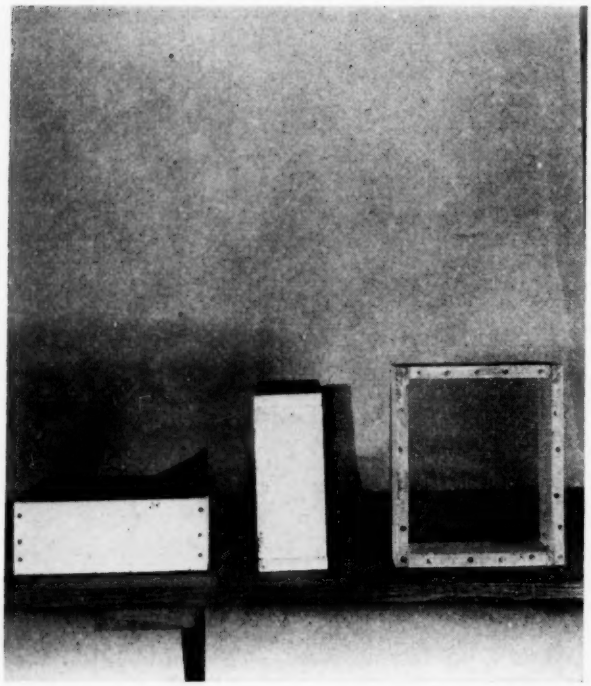


FIG. 2.—Sectional cages placed within the large hibernation cages.

6 inches of snow when the air temperature was minus 27°.

Prolonged subzero weather, however, materially reduced the temperature of the hibernation material even under snow cover. In the winter of 1932–33, when there were many days of subzero weather, the temperature of the hibernation material under snow cover was reduced from 33° on December 16 to 23° F. on February 8. It was noted that beetle mortality was very high at this time whereas in other winters the mortality was at its lowest during this period. The mortality tended to decrease toward the end of each season except 1930–31, when there were insufficient data to indicate any tendency.

The season of 1933–34 was above normal in temperature and below normal in snow cover. The minimum air temperature was 2° F., but there was no snow cover in the cages for more than a few days at a time, and the temperature of the hibernation material was as low as 17°, much lower than was ordinarily found with snow cover when the air temperature was much colder. Also the hibernation material was dry to the point of crispness, except for short periods following precipitation.

In 1931–32 and 1934–35 beetles hibernated more successfully on the northern slope. This was due to a higher moisture content of the hibernation material and a more even temperature resulting from prolonged periods of snow cover. In 1933–34 hibernation was not so successful owing to the lack of moisture and snow cover on both slopes. In 1932–33 there was a higher mortality on the northern slope caused by a prolonged period of extremely low temperature which was more severe than on the southern slope, which is warmed by the sun on clear days.

Survival of beetles, as indicated by emergence from the large cages and the last examination of sectional cages at the end of each season, is shown in table 2. Survival as shown by emergence from large cages was in most years higher on the southern slope. This is apparently due to higher temperature resulting from exposure to sunlight. Owing to lower temperatures of the hibernation material, beetles emerged later on the northern slope.

In 1933–34, a drought season, the hibernation material was too dry for successful hibernation on either exposure. In 1934–35, another drought season but with somewhat more moisture, the hibernation material on the southern slope was too dry. In these two seasons moisture had a greater effect on successful hibernation than temperature. Survival in the sectional cages was in general slightly

Table 1.—Daily minimum air temperatures and temperatures of the hibernation material with and without snow cover during the coldest periods at Estancia, New Mexico.

Date	Air Temperature	Temperature of Hibernation Material	
		Without Snow Cover	With Snow Cover
1932	° *F.*	° *F*	° *F.*
December 16	−5	12	33
17	−7	11	32
21	−4	13	31
31	−6	10	27
1933			
January 1	−4	11	26
11	−3	13	28
February 4	−3	12	21
8	−3	12	23
1934			
January 8	2	17	31
9	7	18	30
November 30	−2	12	28
December 4	3	14	24
26	9	17	26
1935			
January 2	8	16	36
February 26	−2	14	35

Table 2.—Mexican bean beetles surviving hibernation as indicated by natural emergence in large cages and recovery from sectional cages.

Season	Exposure	Beetles Emerging in Large Cages	Live Beetles Removed from Sectional Cages
		Per cent	*Per cent*
1929–30	South	30	37
1930–31	North	8	9
	South	12	30
1931–32	North	13	16
	South	19	41
1932–33	North	8	9
	South	20	10
1933–34	North	2	6
	South	2	1
1934–35	North	14	23
	South	7	12

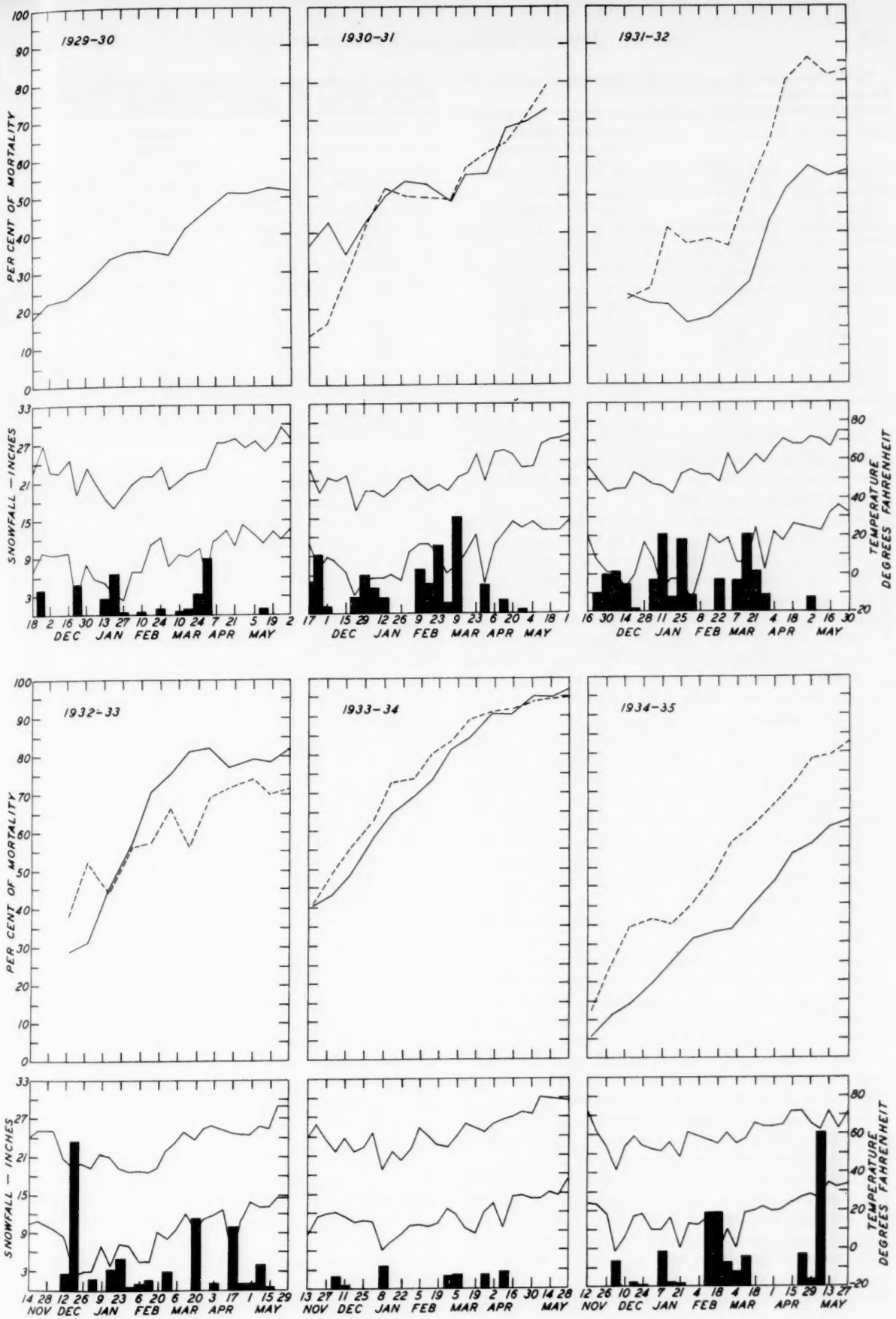


FIG. 3.—Mortality of the Mexican bean bettle and the average weekly temperature and snowfall during the hibernating seasons from 1929-30 to 1934-35. The solid lines indicate mortality on the southern slope and the dotted lines that on the northern slope.

Table 3.—Loss of moisture by hibernating beetles exposed in a desiccator.

Days Required for Total Mortality	Per Cent Weight Lost During Exposure	Calculated Moisture Content of Beetles (Per Cent)	
		Total Before Exposure	Lost During Exposure
72	65.8	66.4	99.2
76	65.4	65.8	99.4
78	64.6	65.6	98.4
72	66.7	67.3	99.2
68	66.7	67.4	99.0
68	64.8	65.8	98.4
65	65.8	66.7	98.6
71	64.7	65.6	98.6
Control	15.1	68.0	22.2

Table 4.—Mortality of beetles hibernating under extremely wet and dry conditions at different temperatures.

Temperature ° F.	Condition of Leaves	Average Moisture Content of Beetles (Per Cent)	Average Mortality (Per Cent)
10	Dry	58	91
	Wet	65	100
11	Dry	59	65
	Wet	64	96
13	Dry	58	28
	Wet	65	65
15	Dry	58	14
16	Wet	67	85
20	Dry	60	35
	Wet	69	96
21	Dry	59	28
	Wet	68	90
30 (Check)	Moist	61	3

higher than in the large cages, owing to a better covering of hibernation material. However, the last examination of sectional cages was made before all the beetles had emerged from the large cage.

During the six seasons the survival in the sectional cages on both slopes ranged from 1 to 41 per cent, whereas emergence from the large hibernation cages ranged from 2 to 30 per cent. These results are comparable to the findings of other investigators. Howard & English (1924) found 14.6 per cent survival in two cages at Birmingham, Alabama, in the season of 1921–22. They also report that the survival in a cage on Lookout Mountain in Tennessee was 9.7 per cent, and farther south at Thomasville, Georgia, 30 per cent. Eddy & McAlister (1927) working in South Carolina, found a survival of 14.2 per cent in 1924–25. Chapman & Gould (1928) in Virginia reported a survival of 15 per cent in 1928. The following season they obtained 58 and 66 per cent in two hibernation cages.

Laboratory Studies.—The effect of the lack of moisture on hibernating beetles was studied in the laboratory. On December 17, 1934, samples of 20 beetles each were exposed in a desiccator containing calcium chloride at normal hibernating temperature until all the beetles were dead. The samples were weighed at the beginning and again at the end of the experiment. A check sample of 20 beetles was held under normal conditions in which the hibernating material was kept moist at all times.

All the beetles exposed in the desiccator were dead in 65 to 78 days, and they lost from 64.6 to 66.7 per cent in weight. With beetles held under normal hibernating conditions for 78 days, only 5 per cent mortality and 15.1 per cent loss in weight resulted. At the end of the experiment the samples were dried in a constant-temperature oven at 212° F. to determine their moisture content. The loss of moisture in the exposed samples was 98.4 to 99.4 per cent in comparison with a loss of only 22.2 per cent in the beetles held under normal conditions (Table 3).

Experiments were conducted to determine the effect of excessive moisture on beetles hibernating at different temperatures. Beetles were exposed for 2 days in a constant-temperature cabinet under different moisture conditions. Some of the beetles were exposed in very dry oak leaves and others in very wet leaves. Check beetles were held in moist leaves at 30° F., which are approximately natural hibernating conditions. A sample of 20 beetles was used in each test, and the tests were replicated four times. At the end of the exposure period the beetle mortality was recorded. Each sample was then weighed, dried at 212° F., and again weighed to determine the moisture content of the beetles. The results of these tests are shown in table 4.

These data show that either excessively wet or dry hibernation material is detrimental to successful hibernation of beetles, but dry conditions are more favorable than the wet. Beetles exposed in the wet leaves contained approximately 8 per cent more moisture than those in the dry leaves, and 5 per cent more than in the moist leaves (check). More moisture was absorbed by the beetles exposed at the higher temperatures. The mortality of beetles in the wet leaves averaged 45 per cent more than that of beetles in the dry leaves. This difference increased with higher temperatures.

Summary.—The winter mortality of the Mexican bean beetle, *Epilachna varivestis* Muls., in the Estancia Valley of New Mexico has been studied in relation to various weather factors in six seasons from 1929–30 to 1934–35. The beetles were placed in hibernation cages in the western yellow pine forest and provided with a cover of oak leaves and pine needles.

Snow coverage was found to contribute to successful hibernation. The temperature of the hibernation material under snow was as much as 21° F. higher than that without snow cover. However, in a prolonged period of subzero air temperatures, such as occurred in 1932–33, the temperature of the material under snow dropped materially, and mortality was high. The mortality was generally lowest toward the end of the season just before emergence.

Under optimum conditions of moisture and temperature, a northern slope was more favorable to successful hibernation than a southern slope, owing to less fluctuation of moisture and temperature. In seasons when the average temperatures were high and there was little moisture and snow cover, the benefit was slightly in favor of the northern slope, probably owing to a higher moisture content of the hibernation material. In seasons of pro-

longed subzero temperatures, as in 1932–33, the beetles on the northern slope showed a higher mortality.

Laboratory studies showed that either excessively wet or dry materials were detrimental to successful hibernation. Beetles exposed in wet leaves contained approximately 8 per cent more moisture than those exposed in dry leaves. At 10° F. all the beetles exposed in wet leaves and 91 per cent of those in dry leaves were killed. At 21° F. for 2 days there was 90 per cent mortality in the wet leaves and 28 per cent in the dry leaves. Beetles held for 2 days in moist leaves at 30° F. showed only 3 per cent mortality.

REFERENCES CITED

Chapman, P. J., and G.E. Gould. 1928. The Mexican bean beetle in eastern Virginia. Va. Truck Expt. Sta. Bull. **53.**

Douglass, J. R. 1933. Hibernation of the Mexican bean beetle in the Estancia Valley, New Mexico. Jour. Agr. Res. **31:** 579–605.

Eddy, C. O., and L. C. McAlister, Jr. 1927. The Mexican bean beetle. S. C. Agr. Expt. Sta. Bull. **236.**

Howard, Neale F., and L. L. English. 1924. Studies of the Mexican bean beetle in the Southeast. U. S. Dept. Agr. Bull. **1243.**

Control of the Grape Mealybug in California[1]

E. M. STAFFORD and H. KIDO, *University of California, Davis*[2]

Grape mealybugs can turn a bunch of fancy table grapes into a sticky, sooty, altogether unattractive mess. In recent years, this insect, *Pseudococcus maritumus* (Ehrh.), has prevented an increasing portion of the yield of some vineyards from reaching the fresh table grape market. A. J. Flebut (unpublished information), in the early 1920's, had proposed a late dormant spray of lime-sulfur and oil for mealybug control on grapes. In many cases growers failed to obtain good results with this spray. Demaree & Still (1951) recommended a spray of parathion wettable powder 2 weeks before bloom or 6 to 8 weeks after bloom in the eastern United States. Frick (1952) obtained control in Washington with a late July spray of parathion wettable powder. In California the presence of "bloom" on table grapes is highly desirable, especially in making fancy packs of dark colored grapes. Any spray applied after the berries have reached "Buckshot" size may cause a spotting or otherwise impair the attainment of "bloom." Hence growers must apply sprays in dormant season and in the spring or, after the berries have begun to size, control their pests with dusts. Growers have more time and a long period in which to apply dormant sprays. In the spring they are busier and have a shorter period for spraying.

Jensen *et al.*, (1954) reported control with sprays of parathion emulsifiable concentrates applied during the dormant season and in March up to the time of budswell. At the concentration used, 600 gallons of spray per acre were necessary. Control was also obtained by two applications of parathion spray in May. Further tests were made in 1954.

METHODS.—The tests in 1954 consisted of sprays applied during the dormant season. Sprays were applied by hand-held spray guns. In our experience there was less fine spray produced and less spray deflected from the vines (and thus wasted) at lower pressures (about 250 p.s.i.). Lower pressures also enabled sprayers to obtain better spray coverage and more easily avoid getting wet when spraying dormant vies. An effort was made to spray thoroughly the rough heavy bark of the vines when comparing different insecticides. Nevertheless, many clusters of very young mealybugs still in the egg sacs under the bark were not reached by the sprays. In fact, the inner bark of the trunks and arms of large old vines was poorly wetted by the sprays used.

The effectiveness of the sprays was measured by making counts of bunches of grapes showing either mealybugs or honeydew only. In July, mealybugs of second generation were most easily found on bunches of grapes that were in contact with the rough bark of the older wood. At these points of contact the young mealybugs gathered together in groups to feed on the berries. Although the mealybugs were more dispersed over the vine by harvest time, they were still most frequently found in bunches which were in contact with the loose bark of the older wood.

RESULTS.—Tests were made on lightly infested mature Emperor grapes. From counts made on September 15 (data not given) it appeared that sprays containing parathion resulted in from 94 to 100 per cent clean bunches. The gallons of spray per vine in different plots ranged from 0.6 to 2.25 and the pounds of active ingredient applied per vine ranged from 0.005 to 0.01. Sprays of DN-289 (2 quarts per 100 gallons of water) and 25 per cent malathion wettable powder at 4 pounds per 100 gallons of water gave about 80 per cent clean bunches at harvest. Sodium arsenite concentrate (6 pounds As_2O_3 per gallon) at 2 quarts per 100 gallons of water gave 52 per cent clean bunches. Emphasizing the lightness and variability of the infestation, the untreated plot showed 93 per cent clean bunches and a spray of 25 per cent malathion wettable powder at 2 pounds per 100 gallons of water showed 100 per cent clean bunches.

Another series of tests was made in a very heavily infested vineyard of mature Alicante grapes. The results are given in table 1. Casual observations in the field a week after spraying showed that only about 10 per cent of the young mealybugs were dead on vines receiving parathion treatments. Sixteen days after treatment from 40 to 50 per cent were dead and on March 16 (35 days after treatment) it was extremely difficult to find live mealybugs on parathion-treated vines. Analyses of bark from the second treatment (Table 1) showed 227 p.p.m.

[1] Accepted for publication October 28, 1954.
[2] The help of Fred Jensen, Farm Advisor in Tulare County, was invaluable in conducting these tests.

Table 1.—Control of grape mealybugs on Alicante grapes.[a]

Materials per 100 Gallons	Spray per Vine (Gal.)	Active Ingredient per Vine (Lb.)	Clean Bunches (Per Cent)
Parathion (xylene base),[b] 1 pt.	1.0	.006	57.1
Parathion (xylene base), 1 pt.	1.5	.008	65.4
Parathion (xylene base), 3 pts.	0.7	.010	68.9
Parathion (xylene base), 2 pts.	0.9	.009	72.6
Parathion (xylene base), 1 pt.; dormant oil emulsion, 2 gals.	1.5	.007	79.4
Parathion (unknown solvent),[b] 1 pt.	1.6	.008	92.0
Parathion (flowable emulsion),[b] 1 pt.	1.6	.008	52.3
Parathion (flowable emulsion), 1 pt.; sugar, 2 lbs.	1.1	.006	66.3
Parathion (flowable emulsion), ½ pt.; sugar, 2 lbs.	1.6	.004	40.9
Sulfotepp,[c] 1 pt.	1.6	.008	64.6
Chlorthion,[d] 1 pt.	1.6	.009	12.6
Holcomb 326,[e] 1 qt.	1.6	.008	21.7
Methyl parathion,[e] 1 qt.	1.6	.008	24.9
Unsprayed	—	—	6.6

[a] Grapes were sprayed at 450 p.s.i. February 8–9 and 350 bunches per treatment were examined at harvest, September 14, 1954.
[b] Contained 4 lbs. parathion per gallon.
[c] Emulsifiable, contained 4 lbs. active ingredient per gallon.
[d] Emulsifiable, contained 6 lbs. active ingredient per gallon.
[e] Emulsifiable, contained 2 lbs. active ingredient per gallon.

parathion initial deposit, 162 p.p.m. 16 days after spraying, 142 p.p.m. 23 days after spraying, and 107 p.p.m. 30 days after treatment. The facts that many of the mealybugs were not wet with the spray and that a high parathion residue remained in the bark for so long a time suggest a slow kill by fumigant action.

With the xylene base emulsifiable parathion (Table 1) there was a close relation between the per cent of clean bunches and the amount of parathion applied per vine. The relation between amount of clean fruit and gallons of spray per vine was not so apparent, though coverage seemed to be a factor in control. When approximately the same amount of parathion per vine was applied the vines receiving a higher gallonage of spray showed cleaner fruit.

The emulsifiable parathion with unknown solvent gave the best results. The flowable parathion was the least effective of the three proprietary preparations. It was noted, however, that the most effective material had been applied to vines on which there were few bunches resting on the old bark. There was thus less opportunity for the bunches to become infested. It is doubtful that the superiority of this material was as great as the data indicate.

The increase in effectiveness of the flowable parathion with addition of sugar appeared to be significant. Dormant oil emulsion, too, increased the effectiveness of the xylene base parathion. Of the other phosphate insecticides tested only sulfotepp showed control comparable to parathion.

Table 2 summarizes the results of sprays applied to mature White Malaga grapes heavily infested with mealybugs. The same relationship between amount of parathion applied, the gallons of spray per vine, and per cent clean bunches found in the case of the Alicante grapes held for sprays applied to White Malagas. In other words, good control was obtained with reduced gallonage of spray so long as sufficient parathion was applied. Again, the parathion concentrate with unknown solvent

Table 2.—Control of grape mealybugs on White Malaga grapes.[a]

Material per 100 Gallons	Spray per Vine (Gal.)	Active Ingredient per Vine (Lb.)	Clean Bunches (Per Cent)
Parathion (xylene base),[b] 1 pt.	1.3	.006	81.4
Parathion (xylene base), 1½ pts.	0.9	.007	86.0
Parathion (xylene base), 2 pts.	0.7	.008	83.0
Parathion (xylene base), 3 pts.	0.7	.011	93.7
Parathion (solvent unknown),[b] 1 pt.	1.2	.006	91.4
Parathion (solvent unknown), 1 pt.; Sodium arsenite,[c] ½ gal.	1.2	.006	95.4
Diazinon,[d] 1 qt.	1.2	.006	41.4
Unsprayed	—	—	2.5

[a] Grapes were sprayed at 250 p.s.i. February 9 and 350 bunches per treatment were examined on September 14, 1954
[b] Contained 4 lbs. parathion per gallon.
[c] Contained 6 lbs. As_2O_3 per gallon.
[d] Contained 2 lbs. active ingredient per gallon.

was more effective than the xylene base parathion concentrate.

The combination of parathion and sodium arsenite gave somewhat better control than parathion alone. This is important since it makes possible the control of mealybugs and black measles of grapes with one spray application.

Two cases of commerical control of mealybugs in the summer are of interest. In the first case the infestation on early Thompson Seedless grapes became evident in late May at which time a 2 per cent parathion dust had little effect. In mid June eggs were hatching in the bark and the young were moving to the leaves. At this time a 2 per cent parathion dust at 35 pounds per acre gave good control though the kill was slow. In another Thompson Seedless vineyard the development of the mealybugs was slower and the eggs began to hatch in late June. A parathion spray applied in early July controlled the mealybugs in this second vineyard. Proper timing was apparently necessary for good control with parathion in the summer. It is often difficult, however, to use parathion in the summer without creating a hazard to people working in contact with the vines later (throwing canes over trellises, leaf thinning, etc.).

SUMMARY.—Experiments of the 1954 season show that grape mealybugs may be controlled with dormant sprays of parathion at gallonages per acre that are economical. The mealybug control may be combined with a sodium arsenite spray for black measles. Damage from mealybug infestations found in table grapes in the summer time may be held at a minimum by parathion treatment. However, cultural practices must be managed to eliminate hazard to workers who must handle the vines.

REFERENCES CITED

Demaree, J. B., and G. W. Still. 1951. Control of grape diseases and insects in eastern United States. U.S.D.A. Bull. **1893.**

Frick, K. E. 1952. The value of some organic phosphate insecticides in control of grape mealybug. Jour. Econ. Ent. **45**(2): 340.

Jensen, Fred, E. M. Stafford, and R. A. Break. 1954. The grape mealybug. Calif. Agr. **8**(3): 11.

Pre-Bloom Treatments to Control European Red Mite Eggs on Pears in Northern California[1]

HAROLD F. MADSEN AND ARTHUR D. BORDEN, *University of California, Berkeley*

European red mite, *Metatetranchus ulmi* (Koch), is one of the major pest problems in California pear orchards; it is a difficult mite to control, especially in cases where high populations exist.

Under California conditions, the European red mite hatches from the overwintering egg shortly after the petal fall period in April. If temperatures remain cool during the early season, the mites do not develop damaging populations until June; but if a period of warm weather occurs during April and early May, high populations can build up in the very early season with a good deal of early foliage damage resulting from mite feeding. Pear foliage is rather susceptible to mite attack, and a population of four to five mites per leaf can cause leaf bronzing and leaf burn.

Most of the available acaricides which could be used for European red mite control are apt to cause foliage or fruit damage when used at the petal fall stage or shortly thereafter. The organic phosphates are an exception, and can be used without fear of injury, but the European red mite appears to have developed resistance to the phosphate compounds in several California pear districts.

In an effort to obtain control of the European red mite in the egg stage, and eliminate the necessity of early foliage treatments, experimental work was started on this problem during the winter of 1953.

Many acaricides show considerable differences in effect when applied to the winter and summer eggs of the European red mite. Hinz (1950) in laboratory tests demonstrated this fact with several acarcides. Ebeling & Pence (1954) also point out the different effects of acaricides when applied to eggs, larvae, and adults of the two-spotted spider mite. Summers & Holmberg (1953) showed that pre-bloom treatments of Ovotran or compound 923 on almonds gave good control of the overwintering brown mite eggs.

STUDIES IN 1952–53.—In the fall of 1952, a plot was established on Bartlett pears in the Santa Clara Valley. The orchard selected had a very heavy population of European red mite eggs, and in addition, it was suspected that resistance to parathion had developed in this orchard.

The plots consisted of 12 trees each and were unreplicated. It was decided to apply materials at several times of the year, post-harvest, dormant, delayed dormant, and at the cluster bud stage. The chemicals were applied with conventional ground equipment and hand guns, and the gallonage averaged 700 gallons per acre.

In an attempt to evaluate the materials prior to the normal hatching of eggs in the field, twig samples were brought into the laboratory and attempts were made to hatch the eggs during the winter and early spring. This technique was not successful, and, therefore, the plots were evaluated by making leaf counts during the foliage season. One hundred leaves were examined per plot at each count date, and the data are expressed as average number of mites per leaf. Table 1 summarizes the materials used, dosages, time of application, and the mite counts. When the mite counts reached an average of four to five per leaf, the plots were retreated with an acaricide to prevent foliage damage.

To summarize the mite counts, DN 289 plus Ovotran as a post-harvest treatment, held the mites in check until late June. Compound 923 as a post-harvest spray was not as effective, and required retreatment in early June. As expected, the dormant oil and delayed dormant DN 289 were fairly effective and held the mites in check until late June. The cluster bud treatments were all applied in combination with lime sulfur-wettable sulfur as in most California areas this is the standard scab spray. Sulphenone was not effective against the European red mite eggs, and required retreatment in April as did the check plot. Ovotran was used at a reduced dosage in the cluster bud spray since previous work has indicated that injury to early blossoms and foliage is apt to result with dosages of $\frac{1}{2}$ pound or more in combination with lime sulfur. The $\frac{1}{4}$-pound dosage used in this test did not cause injury, but also did not control the mite eggs. Compound 923 in the cluster bud treatment gave very good control, holding the mites in check until the latter part of July.

It will be noted in table 1 that during the 1953 season the mite count dropped during the period from May 1 to May 14. This was probably caused by two main factors, one that the mites had completed a generation by that time and were mostly in the egg stage, and secondly, that growth of new leaves during the spring allowed the mites to spread and thus temporarily lowered the individual leaf count.

The results of the preliminary work during 1953 show that the European red mite can be held in check past the early season period, and thus remove the necessity of applying acaricides during the stage when the trees are susceptible to injury.

STUDIES IN 1954.—During 1954, a number of acaricides were tested as pre-bloom treatments to further evaluate this method of mite control. The plots were located in a mixed Hardy and Bartlett pear orchard in the Santa Clara Valley. This orchard had a history of very high European red mite populations during 1953, and egg deposition on the twigs was extremely heavy. The 1953 plots gave indication that populations of European red mite can vary from area to area within a given orchard, therefore, single tree plots were used for each material and were replicated eight times and randomized throughout the plot area. The importance of randomization in this case was considered more vital than the possibility of drift from adjoining trees during the spraying operations. In order to check on the possibility of contamination by drift, 16 check trees were used and were randomized throughout the block.

The standard dormant oil treatment was applied and in addition, combinations of dormant oil with parathion

PAID PAPER.
[1] Accepted for publication November 22, 1954.

Table 1.—Summary of European Red Mite control studies. Santa Clara County, 1953.

Material	Dosage per 100 Gallons	Time of Application	Average Number of Mites per Leaf							
			April 14	April 23	May 1	May 14	June 2	June 24	July 6	July 23
DN-289+Ovotran	4 oz.+1 lb. 50%	Post harvest October 9	0.4	1.4	1.0	0.5	2.2	5.3[a]	—	—
Compound 923	1½ pts. 50%	Post harvest October 9	2.3	1.5	2.4	1.6	4.8[a]	—	—	—
Dormant oil emulsion	5 gallons	Dormant January 16	1.0	1.2	1.8	1.0	3.5	11.0[a]	—	—
DN-289	2 quarts	Delayed Dormant February 12	1.0	1.3	1.5	0.8	2.6	4.5[a]	—	—
Lime-sulfur+wettable sulfur+Sulphenone	2 gallons+4 lbs. +3 lbs. 50%	Cluster bud March 20	6.2	30.8[a]	—	—	—	—	—	—
Lime-sulfur+wettable sulfur+Ovotran	2 gallons+4 lbs. +½ lb. 50%	Cluster bud March 20	4.5	23.4[a]	—	—	—	—	—	—
Lime-sulfur+wettable sulfur+Compound 923	2 gallons+4 lbs. +1½ pts. 50%	Cluster bud March 20	0.3	0.5	0.3	0.2	0.5	1.0	2.0	8.2[a]
Lime-sulfur+wettable sulfur	2 gallons+4 lbs.	Cluster bud March 20	7.6	24.0[a]	—	—	—	—	—	—

[a] Respraying took place at this point.

and malathion. The acaricides were applied at two periods, one at the delayed dormant stage, and the other at the cluster bud stage. All cluster bud treatments were in combination with lime-sulfur, wettable sulfur with the exception of Karathane,[2] as this material possesses fungicidal properties and has been used for scab control.

Materials were applied with conventional ground equipment and orchard spray guns, and gallonage applied

[2] Dinitrocapryl phenyl crotonate.

Table 2.—Dormant and delayed dormant treatments for European Red Mite egg control. Santa Clara County, 1954.

Materials	Dosage	Time of Application	Average Number of Mites per Leaf				
			April 23	May 11	May 24	June 14	July 6
Dormant oil	5 gals.	Dormant—Jan. 5	1.0	1.2	2.8	6.4[a]	—
Dormant oil+Parathion	2½ gals.+2 lbs. 25%	Dormant Jan. 5	0.5	1.4	3.6	5.0[a]	—
Dormant oil+Malathion	2½ gals.+4 lbs. 25%	Dormant Jan. 5	2.5	2.5	11.4[a]	—	—
Ovotran	1 lb. 50%	Delayed Dormant Feb. 22	1.4	1.0	4.7[a]	—	—
Compound 923	1½ pts. 50%	Delayed Dormant Feb. 22	0.5	1.0	1.5	2.0	9.5[a]
Karathane	1½ lbs. 25%	Delayed Dormant Feb. 22	2.0	2.3	6.7[a]	—	—
Chlorobenzilate	1½ lbs. 25%	Delayed Dormant Feb. 22	4.0	2.7	9.6[a]	—	—
Mitox	2 lbs. 20%	Delayed Dormant Feb. 22	0.5	0.2	0.4	0.7	8.5[a]
DMC	1½ pts. 25%	Delayed Dormant Feb. 22	3.5	2.5	8.5[a]	—	—
Check	No spray	—	4.1	4.0	14.4[a]	—	—

[a] Respraying took place at this point.

Table 3.—Cluster-bud treatments for European Red Mite egg control. Santa Clara County, 1954.

MATERIALS	DOSAGE	TIME OF APPLICATION	AVERAGE NUMBER OF MITES PER LEAF				
			April 23	May 11	May 24	June 14	July 6
Compound 923+Lime sulfur +wettable sulfur	1½ pts. 50%+2 gals. +4 lbs.	Cluster-bud March 27	0.4	0.4	0.7	1.0	10.0[a]
Karathane	1½ lbs. 25%	Cluster-bud March 27	2.8	2.0	6.3[a]	—	—
DMC+Lime-sulfur+wettable sulfur	1½ pts. 25%+2 gals. +4 lbs.	Cluster-bud March 27	3.3	3.1	10.6[a]	—	—
Chlorobenzilate+Lime sulfur +wettable sulfur	1½ lbs. 25%+2 gals. +4 lbs.	Cluster-bud March 27	5.3	4.2	13.5[a]	—	—
Mitox+Lime-sulfur+wettable sulfur	2 lbs. 20%+2 gals. +4 lbs.	Cluster-bud March 27	0.5	0.2	0.4	0.6	4.5[a]
Lime-sulfur+wettable sulfur	2 gals.+4 lbs.	Cluster-bud March 27	4.1	4.0	14.4[a]	—	—

[a] Respraying took place at this point.

averaged 700 gallons per acre. As was done during 1953, mite counts were taken during the foliage season to evaluate the materials. At each count, 100 leaves were selected for each treatment, and the active stages of mites counted. The mite counts are expressed as average number of mites per leaf. The material used, dosages, time of application and mite counts are summarized in table 2 for the dormant and delayed dormant sprays, and in table 3 for the cluster bud treatments.

The results of the dormant sprays showed that the parathion-oil combination was as good and perhaps slightly better than oil alone, but the highly hazardous nature of the oil-parathion combination would not justify its use since control of mite eggs was not markedly superior to oil alone. The oil-malathion combination was not effective and required retreatment at the same time as the check plots.

Of the delayed dormant sprays, only compound 923 and *Mitox*[3] gave adequate control of the mite eggs. Some of the other acaricides reduced the mite populations below that of the check, but did not result in commercial control, as four to five mites per leaf is sufficient to cause leaf injury on pear foliage under California conditions.

The cluster bud treatments showed similar results to the delayed dormant sprays. Here again, compound 923 and *Mitox* were the only materials that held the mite populations in check until July. The other materials, although reducing the mite count below the check plots, did not give commerical control.

If a pre-bloom acaricide is applied to pears under California conditions, the most logical time of application is at the cluster bud stage in March. In most of the pear growing areas of California, with the exception of the coastal counties, only one scab spray is applied during pre-bloom, and this treatment is at the cluster bud stage. The inclusion of an acaricide with this treatment would add only the cost of the material to a spray that is a standard practice.

The experimental results do not indicate any difference in control with the effective acaricides between applications at the delayed dormant stage and at the cluster bud stage. Thus far, all the materials used are compatible with lime sulfur, with the possible exception of Ovotran. In order to use this latter material it would be necessary to apply it at the delayed dormant period.

Since it was not possible to obtain early hatching of mite eggs under laboratory conditions, it is difficult to ascertain in what manner the effective materials, compound 923 and *Mitox* act against the overwintering European red mite eggs. Hinz (1953) has shown that a number of acaricides do not actually destroy the eggs, but prevent the nymphal mites from hatching. Other materials may allow the mites to hatch and the residual effect of the acaricide destroys the young mites.

Field examination of eggs after application in the field showed the eggs to be off color, and no indication of developed larvae could be seen. Indications are that compound 923 and *Mitox* do prevent egg development, but laboratory analysis will have to be done before this observation can be confirmed.

SUMMARY.—A number of acaricides were tested as pre-bloom treatments for control of overwintering European red mite eggs. Of the materials tested, compound 923, in tests run for two seasons, held the mites in check until July, *Mitox*, first tested in 1954, gave comparable results. Other materials, although reducing populations below the check level, did not give commerical control. Dormant oil, and a oil-parathion combination controlled the mites until June, but were not as effective as compound 923 and *Mitox* in a pre-bloom treatment. The most logical time to apply acaricides in a pre-bloom spray under California conditions is at the cluster bud stage in combination with lime-sulfur and wettable sulfur for scab control.

REFERENCES CITED

Ebeling, Walter, and Roy J. Pence. 1954. Susceptibility to acaricides of two-spotted spider mites in the egg, larval, and adult stages. Jour. Econ. Ent. **47**(5): 789–95.

Hinz, Howard W. 1953. Laboratory tests of acaricides on eggs of European red mite. Jour. Econ. Ent. **46**(1): 112–5.

Summers, F. M., and D. M. Holmberg. 1953. Early sprays for brown mite. Calif. Agr. **7**(1): 6.

[3] *p*-chlorobenzyl *p*-chlorophenyl sulfide.

SCIENTIFIC NOTES

Transmission of Blueberry-Stunt Virus by *Scaphytopius magdalensis*[1]

KARL MARAMORSCH, *The Laboratories of the Rockfeller Institute for Medical Research, New York*

In 1950 Tomlinson *et al.* (1950) reported the successful transmission of the virus causing blueberry stunt in New Jersey by colonies of leafhoppers containing both *Scaphytopius* (*Cloanthanus*) *magdalensis* and *S. verecundus*. The authors used a "complex" (mixture) of the two species and it could not therefore be determined whether both or only one of the mentioned species was a vector of the causative virus.

In the fall of 1951 leafhoppers of the two species, *Scaphytopius magdalensis* and *S. verecundus*, were obtained from Dr. Martin T. Hutchinson of the Department of Entomology, Rutgers University, New Brunswick, N. J. Blueberry plants, *Vaccinium* sp., were grown from seed obtained from Dr. George M. Darrow of the U. S. Department of Agriculture, Plant Industry Station, Beltsville, Maryland. The seed was derived from a cross of the varieties Scammell × N.C. 246 (Highbush).

Six individual females of *S. verecundus* and six females of *S. magdalensis* were caged by means of screened celluloid cages on young blueberry seedlings planted in 4-inch pots. Some of these original female leafhoppers were impregnated when the test began and colonies appeared on the caged plants. However, no insects were removed and the plants remained caged in a greenhouse for 15 months. Due to dormancy and the resulting lack of food the original females as well as their progeny eventually died. The exposed 12 plants were fumigated and maintained for further observation in a greenhouse for the following 15 months. During the second and the beginning of the third year 3 of the 12 plants were lost. Four surviving plants exposed to *S. verecundus* remained healthy by the end of 30 months. Of the five surviving blueberry plants exposed to single individual *S. magdalensis*, three showed pronounced signs of blueberry stunt by that time. Twenty seedlings from the same lot as the exposed plants, maintained in the same greenhouse, remained healthy.

The number of plants exposed in these tests was comparatively small. The use of seedlings assured virus-free test material. The original insects were caught in the field in Pemberton, N. J., and used immediately for the test without a preliminary feeding on diseased material. The results confirm the transmission of blueberry stunt by *Scaphytopius magdalensis*. The negative transmission test with *S. verecundus* does not eliminate the possibility that *S. verecundus* may be a vector of the blueberry stunt virus. However, Dr. Hutchinson in more extensive tests reported elsewhere in this issue (personal communication) has obtained similar negative transmission results with this species. It appears likely that *S. magdalensis*, but not *S. verecundus*, is responsible for the spread of blueberry stunt in New Jersey.

REFERENCES CITED

Tomlinson, W. E., Jr., P. E. Marucci, and C. A. Doehlert. 1950. Leafhopper transmission of blueberry stunt disease. Jour. Econ. Ent. **43:** 658–62.

PAID PAPER.
[1] Accepted for publication August 20, 1954.

A Note on Domestic Cockroaches in South Texas[1]

RICHARD P. DOW, *Communicable Disease Center, Public Health Service, U. S. Department of Health, Education, and Welfare, Atlanta, Ga.*

In connection with studies of dysentery and poliomyelitis in Hidalgo County, Texas, in 1948, the writer supervised the trapping of cockroaches in the towns of Pharr and Donna for a period of several weeks. Since traps were operated simultaneously in houses and outdoor privies, the records provide an interesting comparison of these two habitats. The primary reason for making the collections was to learn whether poliomyelitis virus occurred in cockroaches, and if so, under what conditions. In fact, when some of the specimens were later tested by Dr. J. T. Syverton at the University of Minnesota, one pool was proved positive for poliomyelitis. This pool consisted of 106 *Blattella* and 7 *Periplaneta* which had been caught on the premises of a householder in Pharr (personal communication from Dr. J. T. Syverton; see also Syverton and others, Federation Proc. 11(1): 483, 1952). Unfortunately, in the press of collecting and preparing these insects, the specimens were identified to genus only. This was of no consequence with respect to *Blattella*, which is represented in the United States by one species, *B. germanica* (L.), but recent identification of 83 *Periplaneta* not used in the virus tests has shown that, at least in the town of Pharr, *P. brunnea* Burm. and *P. americana* (L.) were both present.

Table 1.—Blattella germanica trapped in houses and privies.

	PHARR, TEX.	DONNA, TEX.
No. of house settings positive	80 of 197 (41%)	17 of 234 (7%)
No. of house sites positive	29 of 33	12 of 39
No. of roaches trapped in houses	1561	51
No. of privy settings positive	18 of 195 (9%)	0 of 234 (0%)
No. of privy sites positive	11 of 33	0 of 39
No. of roaches trapped in privies	131	0

The traps used to collect the cockroaches were simply 2-quart fruit jars which were baited with bread spread with lard. By means of a loop of wire, the jars placed in outdoor privies were hung on a nail under the privy seat. For each trap set in a privy, another was set in a house in the same yard, usually in the kitchen. In the Latin-American sections where all of the trapping was done, two or more families often live in separate houses in the same yard. They may or may not share one privy. The traps were set on one day and, with a few exceptions, picked up on the day following.

A comparison of the cockroach collections from Pharr and Donna is interesting because Donna was under fly control during the trapping period and had been so since the previous autumn. Pharr, on the other hand, had been under fly control in the previous summer, though not after August. The fly control measures in Donna included frequent spraying with DDT emulsion, both in houses and in privies including the pit.

In order to analyze comparable records, there are considered only the six rounds of trapping which were completed in each town between May 18 and June 23, inclusive. The data are further limited to the collections of 33 pairs of traps in Pharr and 39 pairs in Donna, all of which were operated routinely with a known loss of only four catches. According to these trapping records (Table 1), *Blattella germanica* was much more abundant in houses than in privies and much more abundant in Pharr than in Donna. In spite of possible objections to the type and method of trapping, the general results seem obvious.

When the 392 selected records from Pharr were first analyzed for the occurrence of *Periplaneta* as a genus, the collections positive for the genus were found to be rather evenly divided between houses and privies (25 and 33, respectively). Accordingly, it seemed that there might be considerable migration of the roaches between the two habitats. Later it was possible to make specific identifications of 83 adult specimens not used in the virus tests. Most of these roaches were from the selected col-

PAID PAPER.
[1] Accepted for publication November 19, 1954.

Table 2.—**Periplaneta trapped in houses and privies, Pharr, Texas.**

SPECIES	HOUSES	PRIVIES
P. brunnea	13 males, 23 females	4 males, 1 female
P. americana	2 males, 4 females	4 males, 32 females

lections, but a few had been taken May 13–14 or trapped at other homes. A breakdown of these 83 *Periplaneta* by type of habitat (Table 2) indicates that *P. brunnea* was trapped more frequently in houses and *P. americana* more frequently in privies. This result suggests that migration between houses and privies might not be so frequent as originally supposed, though of course the mere finding of a species in two habitats does not establish any movement between them.

SUMMARY.—In May and June of 1948, simultaneous operation of paired cockroach traps in houses and outdoor privies in south Texas showed that, in a town not under fly control, *Blattella germanica* occurred in 29 of 33 houses and 11 of 33 privies. In the same town, from which one lot of mixed cockroaches was found positive for poliomyelitis, *Periplaneta brunnea* was trapped mostly in houses (36 out of 42 house specimens) and *P. americana* mostly in privies (36 out of 41 privy specimens).

Barrier-Strip Spraying for the Control of Rice Field Mosquitoes[1]

K. D. QUARTERMAN, J. A. JENSEN, WILLIS MATHIS, and WILLIAM W. SMITH

Almyra, Arkansas, was selected as an experimental site to determine the feasibility of barrier strip spraying as a method of protecting towns and communities against the influx of rice field mosquitoes. This town has a population of approximately 250 and is located in a large rice-producing section of Arkansas. Some rice fields extended into the edges of the town, and it was necessary to apply the barrier in an irregular pattern in order that no rice fields would be within the treated area. The vegetative cover in the barrier strip was relatively sparse, as a considerable part of the treated area was pasture land.

A strip 400 feet wide was treated around the town on the morning of July 25, 1952. The concentrate used contained 3 pounds of DDT per gallon and 2.5 per cent emulsifier. The ratio of water to concentrate in the finished spray was $\frac{1}{3}$ gallon of water to $\frac{2}{3}$ gallon of concentrate. This spray was applied with a Stearman PT-17 airplane using #8015 Spraying Systems Co.[2] nozzles. The height of the plane when spraying was approximately 30 feet and the indicated speed was 80 m. p. h. The discharge rate was 3 pounds of DDT per acre.

Ten glass plates, 3 in.×12 in., were placed in pairs at 100-foot intervals across the barrier on one side of town during treatment to obtain an indication of the dosage at ground level. These plates were in vegetation approximately 18 inches high, which undoubtedly prevented some of the spray from reaching the slides. The amounts recovered, as determined by chemical analysis, were 0.35, 1.05, 1.21, 1.09, and 0.74 pounds of DDT per acre beginning at the inner margin of the barrier and at each 100-foot interval, respectively, to the outer margin.

On the morning of July 26 the area within the barrier was sprayed by the same plane. Number 8004 Spraying Systems Co. nozzles were used for this space spray treatment which was ap-

[1] Contribution from the Communicable Disease Center, Public Health Service, U. S. Department of Health, Education, and Welfare, Savannah, Georgia. Accepted for publication September 13, 1954.

[2] Trade names are used as a means of identifying products. Their use does not constitute endorsement by the U. S. Public Health Service.

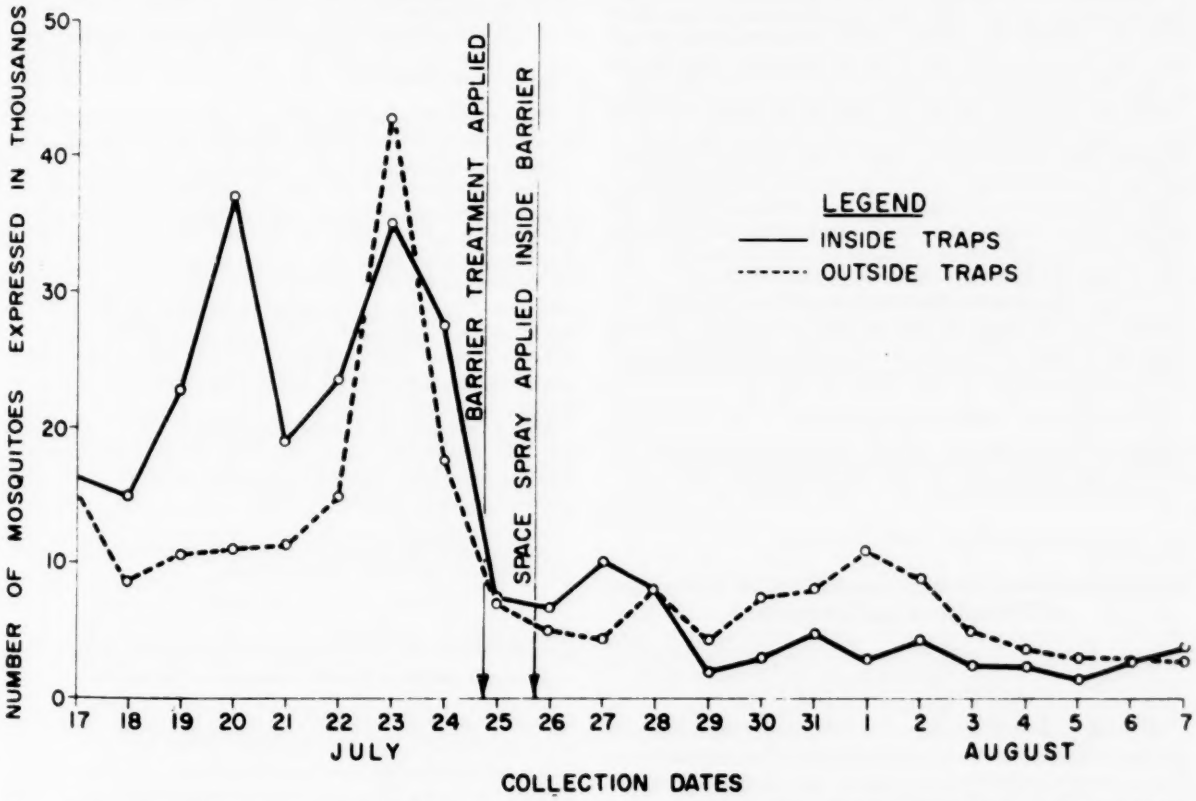


FIG. 1.—Average number of mosquitoes per trap collected inside and outside of a 400 foot barrier around Almyra, Ark., treated by airplane with DDT residual spray at an output dosage rate of 3 lb. of DDT per acre on July 25, 1952.

plied at the discharge rate of 0.2 pound of DDT per acre. This spray was applied to eliminate any adult mosquitoes that might have been within the barrier at the time it was treated.

New Jersey-type light traps (Mulhern 1942) were used to measure the pretreatment and posttreatment mosquito populations. One trap was located near the center of the town and a single trap was placed on each of four sides of the town within the barrier strip. For each of the traps placed within the barrier, with the exception of the trap in the center of town, a corresponding trap was located outside of the treated area as near to the inside trap as possible. These traps were operated for nine consecutive nights before the treatment was applied to determine the ratio of the number of mosquitoes caught by traps located within the proposed barrier to those on the outside of the barrier. After the treatment was applied, the traps were operated for 13 nights. No sampling was done during the day since the species involved do not usually move from the vicinities of their resting places during the day, although they will fly out of these places and feed on passing animals.

Because of the large numbers of mosquitoes caught in the traps, it was impractical to count all of them. An aliquot sample was taken from each and counted according to species. The number in the entire catch was then estimated. *Psorophora confinnis* L.-A. represented about 73 per cent of the total mosquito population in the area during the experiment, and *P. discolor* Coq. about 25 per cent.

Figure 1 gives the trend of the mosquito populations for the traps located within and outside of the barrier strip for the duration of the experiment. In general, the population trend, as indicated by the light trap collections, was quite similar inside and outside of the barrier throughout the experiment. The peak of the population was apparently reached on the night of July 23 in both the inside and outside traps. The collections on the night of July 24 showed a sharp decrease in each series of traps and this continued on the night following the barrier treatment. Based on the collections of the outside traps, which should not have been influenced too greatly by the treatment, this appears to have been a natural decline. However, even though the decline may have been partially effected by the barrier spraying, satisfactory control was not obtained, since an average of about 7,000 to 10,000 mosquitoes was collected per trap inside the barrier for the first four nights following treatment, and the average per trap collection inside the barrier ranged from approximately 1,400 to 4,700 mosquitoes nightly throughout the balance of the experiment. Individual trap catches inside the barrier after treatment numbered up to approximately 16,500 mosquitoes.

ACKNOWLEDGMENTS.—The authors gratefully acknowledge the assistance of Mr. John E. Taylor, Mr. L. C. Smith, and the Arkansas State Board of Health in supplying the materials, part of the equipment, and some of the personnel used in this study.

REFERENCES CITED

Mulhern, T. D. 1942. New Jersey mechanical trap for mosquito surveys. N. J. Agr. Exp. Sta., Cir. 421.

Persistence and Fumigation Effect of a Residue of Parathion and Demeton[1]

GEORGE V. JOHNSON, *Entomology Research Branch*, Agr. Res. Serv., *U.S.D.A.*, and WILLIAM A. FEDER,[2] *Department of Plant Pathology*, Cornell University

In connection with investigations on pests of greenhouse and ornamental plants conducted during 1953 at Farmingdale, New York, some information was obtained on the persistence and fumigation effect of a residue of parathion and demeton.

A 55-cubic-foot fumigation chamber was used, which had a galvanized-iron lining with soldered joints and air-circulating equipment consisting of a small fan and 2-inch iron pipe. One side (2½ by 8 feet) of the chamber was removable to serve as a door. Except for the time that testing was in progress, the door was left open. Five treatments with 10 per cent aerosols were made at the following rates per 1000 cubic feet.

Parathion	*Demeton*
March 16—1 oz.	March 27—1 oz.
23—2 oz.	30—2 oz.
24—1 oz.	

Each exposure was for 24 hours except the one with parathion on March 24, which was for 48 hours.

Following the aerosol treatments, attempts to clean the fumigation chamber were made as follows:

April 1—Chamber scrubbed with water and a detergent.
2—Chamber cleaned with steam.
3—Circulating equipment dismantled. Chamber and equipment scrubbed with hot water and a detergent and rinsed.

These efforts were not successful, as shown by high mortalities of tulip bulb aphids, *Anuraphis tulipae* (Fonsc.), confined in the chamber for several hours after each cleaning.

When it became apparent that the insecticidal effect was persistent, several overnight exposures of aphids were made during the period April 9 to July 10 and the mortality determined. Exposures ranging from 16 to 21 hours were made at temperatures of 70° to 80° F. Counts made 4 days after exposure are summarized in table 1. The aphid mortalities for the last four exposures were corrected for a high natural mortality, by use of Abbott's formula. The data show that the effect of the residue was persistent and declined slowly over more than a 3-month period.

Table 1.—Mortality of tulip bulb aphids exposed overnight in a fumigation chamber from 14 to 106 days after the last treatment with parathion and demeton aerosols.

DAYS AFTER LAST TREATMENT	NUMBER OF APHIDS	PER CENT MORTALITY
14	532	85
18	203	63
21	636	47
25	749	74
28	691	66
38	1238	53
63	699	23
75	776	19
81	4040	17
106	2043	25

After 1 year some insecticidal effect still remained in the chamber. This was shown when tulip bulb aphids confined in the chamber overnight exhibited uncoordinated movements and a tendency to leave the infested bulbs.

[1] Accepted for publication September 15, 1954.
[2] Formerly agent and now nematologist with Horticultural Crops Research Branch, Agricultural Research Service, U.S.D.A.

Penetration of Additional Packaging Films by Common Stored-Product Insects[1]

PAUL D. GERHARDT and DAVID L. LINDGREN, *University of California Citrus Experiment Station, Riverside*

Since publishing the results of the work on "Penetration of Various Packaging Films by Some Common Stored-Product In-

[1] Accepted for publication September 27, 1954.

Table 1.—Penetration of various packaging films by adults and larvae or nymphs of ten species of common stored-product insects in "lard can tests."

PACKAGING FILM	PERCENTAGE OF PACKAGES PENETRATED	AVERAGE NUMBER OF WEEKS REQUIRED FOR PENETRATION
Single layer films		
Mylar 0.001 inch thick	10.5	6.0
450 MST cellophane 0.0014 inch thick	61.0	1.8
Polyethylene 0.0015 inch thick	61.0	1.5
Laminated films		
S-517 DW Saran 0.001 inch+ Mylar 0.001 inch thick	0.0	0.0
S-517 Saran 0.002 inch thick+ Mylar 0.001 inch thick	0.0	0.0
N-684 Saran 0.002 inch thick+ Mylar 0.001 inch thick	0.0	0.0

sects" (Gerhardt & Lindgren 1954), the authors have run a series of similar tests on a transparent packaging film called Mylar.[2] As in the previously mentioned article, the species of insects used in the present tests were as follows: The granary weevil, *Sitophilus granarius* (L.); the rice weevil, *Sitophilus oryzae* (L.); the lesser grain borer, *Rhyzopertha dominica* (F.); the cadelle, *Tenebroides mauritanicus* (L.); the saw-toothed grain beetle, *Oryzaephilus surinamensis* (L.); the confused flour beetle, *Tribolium confusum* Duv.; the drug-store beetle, *Stegobium paniceum* (L.); dermestid beetle, *Trogoderma parabile* Beal; Mediterranean flour moth, *Ephestia kühniella* Zell.; Indian-meal moth, *Plodia interpunctella* (Hbn.) and the German cockroach, *Blattella germanica* (L.).

The transparent films used in the present tests were the following:

1. Single layer film, 0.001-inch thick Mylar.
2. Laminated film.[3]
   (a) 0.001-inch thick Mylar, plus 0.001-inch thick S-517 DW Saran.
   (b) 0.001-inch thick Mylar, plus 0.002-inch thick S-517 Saran.
   (c) 0.001-inch thick Mylar, plus 0.002-inch thick N-684 Saran.
3. Previously tested films included for comparison:
   (a) 0.0014-inch thick 450 MST Cellophane.
   (b) 0.0015-inch thick Polyethylene.

The results given in table 1 show that 10.5 per cent of the packages of the single-layer 0.001-inch thick Mylar were penetrated, with an average of 6 weeks required for penetration, while none of the laminated film packages of Mylar plus Saran were penetrated by any of the 10 species of insects tested. In comparison, 61 per cent of the 450 MST Cellophane (0.0014 inch thick) packages were penetrated, requiring only 1.8 weeks average time for penetration. Likewise, 61 per cent of the Polyethylene film (0.0015 inch thick) packages were penetrated, with only 1.5 weeks average required to effect penetration.

The cadelle, which is an effective penetrator, penetrated 12.4 per cent of the 0.001-inch thick Mylar film packages, and the lesser grain borer and dermestid beetle penetrated 6.2 per cent of the packages, respectively. The cadelle and lesser grain borer required an average of 5 weeks to affect penetration, while the dermestid beetle required an average of 9 weeks for penetration. None of the laminated film packages were penetrated by any of the insect species tested.

These results indicate that transparent laminated films having Mylar as the external lamina were highly effective in resisting penetration by the 10 species of stored-product insects tested.

REFERENCES CITED

Gerhardt, Paul D., and David L. Lindgren. 1954. Penetration of various packaging films by common stored-product insects. Jour. Econ. Ent. **47**(2): 282–7.

[2] Manufactured by E. I. du Pont de Nemours & Company, Inc.
[3] Mylar was the outside lamina in the three laminated films tested.

Toxicity of Several Insecticides to House Fly Larvæ[1]

H. B. CUNNINGHAM and W. G. EDEN,
A.P.I. Agr. Expt. Sta., Auburn

There has been considerable interest in Alabama for the past few years in the use of larvicides for control of the house fly, *Musca domestica* L. Several investigators have reported on the use of chlorinated hydrocarbons as larvicides against the house fly. Tanada *et al.* (1950) obtained control of house fly larvae in Hawaii with 0.5 per cent DDT emulsion sprays applied to poultry manure. Wolfenbarger & Hoffman (1944) reduced by 90 per cent the emergence of house flies from poultry manure by spraying the manure with DDT. Furman (1946) and Travis & Bohart (1946) secured good control of flies in pit latrines with 5 per cent DDT oil solutions or emulsions. McGovran *et al.* (1944) obtained 77 per cent kill of house fly larvae by introducing 60 mg. of DDT into 23 g. of larval medium. McDuffie *et al.* (1946) found that 5 per cent DDT applied to larval medium had very little effect on the larvae but killed most of the adults as they emerged. Control of house fly larvae in the laboratory was obtained by Hadjinicalaon & Hansens (1953) with small amounts of dieldrin, aldrin, chlordane, and heptachlor. Mayeux (1954) in working with malathion, found that a spray containing 1 per cent malathion applied to manure at the rate of 1 gallon per 100 square feet was very effective against fly larvae.

Experiments were conducted in 1952 on the toxicity of endrin, dieldrin, aldrin, chlordane, and DDT to third-instar larvae of the house fly, the results of which are presented in this report.

PROCEDURE.—A culture of house flies was started from adults collected at the dairy barn of the Agricultural Experiment Station at Auburn. The adult flies were fed condensed milk and water mixed in equal parts. The medium used for rearing the larvae was modified from that used by Harrison (1949). It was prepared by combining two parts by weight of wheat bran to one of alfalfa meal. Ten gm. of compressed yeast and 16 ml. of malt extract in enough water to make 1 liter were added to 500 gm. of the mixture. The medium was mixed until evenly wetted and placed into a 6-inch battery jar. One-tenth ml. of house fly eggs was placed on top of the medium. The jar was covered with tobacco cloth until the larvae had pupated near the top of the jar. The pupae were separated from the dry medium with screens and placed in cages for emergence. The culture was carried through 15 generations before the maggots were used for testing insecticides.

Each of five insecticides was tested at six concentrations in the larval medium. Endrin, dieldrin, and aldrin were tested at 0, 100, 200, 400, 800, and 1600 p.p.m. Chlordane and DDT were tested at 0, 500, 1000, 2000, 4000, and 8000 p.p.m. The test media were prepared in the same way described above except for the addition of insecticide. The desired amount of insecticide dissolved in acetone was added to the mixture of water, malt extract, and yeast and mixed thoroughly. The liquid was then mixed with dry matter. The same amount of acetone was added to each of the media including the control. The medium was then

[1] The data herein are taken from a thesis presented by the senior author to the Alabama Polytechnic Institute in partial fulfillment of the requirements for the M.S. Degree. Accepted for publication September 27, 1954.

Table 1.—Emergence of adult house flies from media containing various amounts of insecticides.

Concentration of Insecticide in p.p.m.	Per Cent Emergence[a]				
	Endrin	Aldrin	Dieldrin	Chlordane	DDT
100	60.2	95.4	90.9	—	—
200	27.7	90.6	86.0	—	—
400	0.0	54.0	45.7	—	—
500	—	—	—	91.6	92.0
800	0.0	23.4	30.5	—	—
1000	—	—	—	63.0	84.8
1600	0.0	1.3	0.0	—	—
2000	—	—	—	38.9	53.2
4000	—	—	—	13.7	32.8
8000	—	—	—	1.9	16.0
LD-50, p.p.m.	125	430	450	1450	2300
0.95 Fiducial, p.p.m. limits	100–160	340–595	355–595	1100–1900	1600–3300

[a] The per cent emergence was based on emergence of adults from the untreated checks.

spread on paper in a thin layer for 2 hours to allow the acetone to evaporate.

The insecticides were tested in wide-mouthed culture jars 2 inches in diameter and 8 inches high. Medium containing each level of each insecticide was mixed in sufficient quantity for two culture jars so that each material and level was tested in duplicate. At a later date the test was repeated, making a total of four replications. To each culture jar was added 50 third-instar house fly larvae, all of which were reared in the same culture from a single egg mass. The culture jars were covered with tobacco cloth until all adults had emerged and died. All adults were then counted, including those which died before their wings were spread.

The concentrations of insecticide in the media were calculated on the basis of dry matter, exclusive of malt and yeast. All insecticides were of technical grade. The endrin, aldrin, and dieldrin were supplied by the Shell Chemical Corporation, and the chlordane and DDT were A.A.E.E. reference standards. The tests were designed to determine the concentration of insecticide at which 50 per cent of the larvae emerged as adults.

Results.—The results are presented in table 1. The emergence percentages shown in the table were plotted on dosage-mortality curves to determine the concentrations of insecticides at which 50 per cent of the third-instar larvae emerged as adults. Endrin was the most toxic of the five insecticides with an LD-50 concentration of 125 p.p.m. Aldrin and dieldrin were of approximately the same toxicity with LD-50's of 430 and 450, respectively. The fiducial limits of these two compounds overlap, so there was no statistical difference between the two. Chlordane was considerably less toxic than aldrin or dieldrin with an LD-50 concentration of 1450 p.p.m. DDT was the least toxic of the five insecticides with an LD-50 of 2300 p.p.m.

Summary.—Laboratory experiments were conducted to determine the LD-50 concentrations of endrin, aldrin, dieldrin, chlordane, and DDT in the larval medium to third-instar house fly larvae. The emergence of adult flies was used as a measure of toxicity. Endrin was the most toxic with an LD-50 concentration of 125 p.p.m. in the medium. The LD-50 concentrations of aldrin, dieldrin, chlordane, and DDT were 430, 450, 1450, and 2300 p.p.m., respectively.

References Cited

Furman, D. P. 1946. Use of DDT in control of latrine flies. Jour. Econ. Ent. **39**(4): 541–2.

Hadjinicalaon, J., and E. J. Hansens. 1953. Chlorinated hydrocarbon insecticides to control house fly larvae. Jour. Econ. Ent. **46**(1): 34–7.

Harrison, R. A. 1949. Laboratory breeding of the house fly, *Musca domestica* L. New Zea. Jour. Sci. and Tech. **30**: 4.

Mayeux, H. S. 1954. Malathion for house fly control. The Fla. Ent. **XXXVII** (2): 97–104.

McDuffie, W. C., A. W. Lindquist, and A. H. Madden. 1946. Control of fly larvae in simulated pit latrines. Jour. Econ. Ent. **39**(6): 743–9.

McGovran, E. R., H. H. Richardson, and P. G. Piquett. 1944. Toxicity of DDT to bedbugs, cockroaches, the Mexican bean beetle, and house fly larvae. Jour. Econ. Ent. **37**(1): 139–40.

Travis, B. V., and R. M. Bohart. 1946. DDT to control maggots in latrines. Jour. Econ. Ent. **39**(6): 740–6.

Tanada, Y., F. G. Holdaway, and J. H. Quisenberry. 1950. DDT to control flies breeding in poultry manure. Jour. Econ. Ent. **43**(1): 30–6.

Wolfenbarger, D. O., and Edmund Hoffman. 1944. Uses of DDT on the poultry farm. Poultry Sci. **23**(6): 545–56.

Injurious Insects Found on Castor Beans[1]

George P. Wene, *Texas Agricultural Experiment Station, Weslaco*

Castor beans were grown rather extensively during 1952 in the Lower Rio Grande Valley of Texas. Research work in the past had led growers to believe that castor beans were free from or resistant to destructive insects. Smith (1939) stated that all castor bean plantings observed were remarkably free from injurious insects. Miller *et al.* (undated) reported that the corn earworm was the only destructive insect on castor beans in Texas, and that it usually defoliated young plants. Watson (1919) reported corn earworm larvae feeding on castor bean pods. A survey during the summer of 1952 in Texas showed three destructive insects.

Serpentine Leaf Miner.—The serpentine leaf miner, *Liriomyza subpusilla* (Frost), was found in destructive numbers in every planting observed. On July 25, a field was observed in which an estimated two-thirds of the leaves had been shed by the plants due to serpentine leaf miner injury. Five leaves were examined at random, and an average of 39 fully developed larvae were seen migrating from the exit holes of the mines to the edge of the leaves. At the same time an average of 10 adult leaf miners were seen either feeding or laying eggs on these leaves.

Leafhoppers.—A leafhopper, *Empoasca solana Del.*, which is commonly found on black-eyed peas and careless weeds were found in large numbers in fields in the Edinburg area on July 23. As many as 39 adults and nymphs were found feeding on a single castor bean leaf. The leafhopper population was so large in one field observed that the castor bean plants shed 50 per cent of their leaves due to the injury caused by the leafhopper's feeding.

Corn Earworm.—On July 23, near Mission, Texas approximately 200 acres of castor beans was infested with corn earworm, *Heliothis armigera* (Hbn.). Larvae in all stages of growth were observed. There was at least one larvae feeding on each flower or seed spike. At that time approximately 75 per cent of the seed pods had been destroyed by this insect. Furthermore, there were from 4 to 5 larvae feeding on the leaves of each plant.

References Cited

Miller, E. A., J. Roy Quinby, B. C. Langley, Joe H. Rothe, Joe R. Walzel, and R. H. Nelson. Undated. Castor beans in Texas. Texas Agr. Ext. Serv. Bull. **195** and Texas Agr. Expt. Sta. Bull. **744.**

Smith, Roger C. 1939. Insect collections and rearing on castor beans with especial reference to grasshoppers. Jour. Econ. Ent. **32**(6): 749–58.

Watson, J. R. 1919. Castor bean insects. In report of the entomologist. Fla. Agr. Expt. Sta. Ann. Rept. **58R-59R.**

[1] Accepted for publication September 30, 1954.

Toxicity of Several Insecticides to Two Strains of the House Fly[1]

A. D. OLIVER and W. G. EDEN, *A.P.I. Agricultural Experiment Station, Auburn*

Within the past 2 or 3 years, it has become increasingly difficult to control the house fly, *Musca domestica* L., with DDT at Auburn, Alabama. It appears that the house fly has become resistant to the insecticide.

It has been well established that the toxicities of chlorinated hydrocarbon insecticides vary considerably from locality to locality and between the many different strains of flies. King (1950) found the LD-50 of DDT for an Orlando special strain of house fly to be 12.3 micrograms per fly, 8.3 for the Bellflower strain, and 0.12 for a laboratory strain. Bruce (1950) reported the LD-50 of flies in terms of micrograms of toxicant per gram of flies. The 24-hour LD-50 of toxaphene to the NAIDM susceptible strain of flies was 29.16 micrograms per gram of flies and 16.8 micrograms of DDT per gram of flies. For a strain of resistant flies, the LD-50's in micrograms per gram of flies were 76.4 and 18,728 for toxaphene and DDT, respectively. Bruce also found the LD-50 of chlordane for the NAIDM strain to be 8.20 micrograms per gram of flies. For the strain that had become resistant to DDT, the LD-50 of chlordane was 15.6 micrograms per gram of flies.

Experiments were conducted at Auburn during the spring and summer of 1954 to determine the extent of resistance in native house flies to DDT, lindane, endrin, TEPP, and malathion.

PROCEDURE.—Two strains of house flies were used in the experiments. A culture of one strain was established from native flies captured at the dairy barn of the A.P.I. Agricultural Experiment Station at Auburn. The other strain was cultured from pupae of non-resistant flies obtained from the U.S.D.A. Entomology Research Laboratory at Orlando, Florida. The strains were designated as Auburn and Orlando, respectively. The difference in the susceptibilities of the two strains was deemed the degree of resistance.

The flies were cultured by a modification of the method proposed by Harrison (1949). Adult flies were fed a 1:1 mixture of evaporated milk and water. The rearing room was always lighted and the temperature was never less than 70° F.

The LD-50's of the insecticides were determined by applying the toxicants in minute droplets to the ventral abdomen of individual flies. The toxicants were dissolved in acetone-water mixtures and applied by the apparatus proposed by Trevan (1922). Two microliters of the solutions were applied to each fly after it had been anesthetized with carbon dioxide.

Five dosage levels of each compound were used to determine the LD-50. Four replications of 25 flies each were used at each dosage level. The flies were 3 to 5 days old. The treated flies were supplied with food and held for 24 hours in screen wire cages. Mortality counts were made 24 hours after the flies were treated. Flies used in the various experiments were weighed to determine the LD-50 in terms of micrograms per gram of flies as well as micrograms per fly. The mortality data were adjusted for the effects of the insecticides according to Abbott's (1925) formula and plotted on dosage-mortality curves from which the LD-50's were read.

RESULTS.—The LD-50's of the five insecticides to both strains of flies are given in table 1. TEPP was the most toxic to the Orlando strain with an LD-50 of 0.19 microgram per fly. DDT was less than one-half as toxic as TEPP, with an LD-50 of 0.45 microgram per fly. Lindane had an LD-50 of 0.75 microgram per fly; however, the 0.95 fiducial limits for DDT and lindane overlap. The LD-50 for malathion was 0.87 microgram per fly but the fiducial limits are inside those for lindane. Of all the insecticides tested, endrin was the least toxic to the Orlando strain, with an LD-50 of 1.90 micrograms per fly.

Table 1.—Toxicities of five insecticides to two strains of the house fly.

Insecticide	LD-50			
	Orlando Strain		Auburn Strain	
	Micrograms per		Micrograms per	
	Fly[a]	Gram of Fly	Fly[a]	Gram of Fly
TEPP	0.16–0.19–0.27	10.4	0.16–0.24–0.35	13.6
DDT	0.42–0.45–0.60	27.5	5.50–6.40–7.20	303.4
Lindane	0.50–0.75–1.25	51.3	1.00–1.25–1.57	80.7
Malathion	0.72–0.87–1.00	47.8	0.92–1.07–1.27	57.3
Endrin	1.55–1.90–2.32	104.4	1.75–2.10–2.50	118.9

[a] The middle figure is the LD-50; others indicate the 0.95 fiducial limits.

To the Auburn strain of fly, TEPP was also the most toxic with an LD-50 of 0.24 microgram per fly. Malathion was next to TEPP in toxicity with an LD-50 of 1.07 micrograms. The fiducial limits of the LD-50 of lindane overlapped those of malathion. Endrin was less toxic than TEPP, malathion, or lindane; the LD-50 for endrin for the Auburn strain was 2.10 micrograms per fly. DDT was by far the least toxic of the five insecticides to the Auburn strain, with an LD-50 of 6.40 micrograms per fly.

With the exception of DDT, there appeared to be no difference in the susceptibilities of the two fly strains to the insecticides. The 0.95 fiducial limits of the LD-50's overlapped between the two strains for each compound except DDT. Based on these data, the Auburn strain of house fly was over 14 times as resistant to DDT as the Orlando strain.

When the LD-50's were calculated in micrograms per gram of flies, the insecticides had the same general order of toxicity as that based on micrograms per fly. Thus differences in susceptibility between the two strains were not due to differences in the size of the flies.

SUMMARY.—The susceptibilities of two strains of the adult house fly, *Musca domestica* L., to five insecticides were determined by topical application. The LD-50's in micrograms per fly of the insecticides to the non-resistant (Orlando) and resistant (Auburn) strains were, respectively, as follows: TEPP, 0.19 and 0.24; DDT, 0.45 and 6.40; lindane, 0.75 and 1.25; malathion, 0.87 and 1.07; and endrin, 1.90 and 2.10.

REFERENCES CITED

Abbott, W. S. 1925. A method of computing the effectiveness of an insecticide. Jour. Econ. Ent. **18**: 265–7.

Bruce, W. N. 1950. Current report on house fly resistance to insecticides. Pest Control **18**(4): 9–10.

Harrison, R. A. 1949. Laboratory breeding of the house fly (*Musca domestica* L.) New Zeal. Jour. Sci. and Tech. **30**: 4.

King, W. V. 1950. DDT resistant house flies and mosquitoes. Jour. Econ. Ent. **43**(4): 527–32.

Trevan, J. W. 1922. An apparatus for measuring small quantities of fluids. Lancet **202**: 786.

[1] The data herein are from a thesis presented by the senior author to the Alabama Polytechnic Institute in partial fulfillment of requirements for the M.S. degree. Accepted for publication October 6, 1954.

EDITORIAL

Distinguished Journalism

Public judgment of the Entomological Society of America is largely influenced by the quality of its publications, and our footprints on the sands of time will be recorded in the orderly rows of the JOURNAL OF ECONOMIC ENTOMOLOGY and the Annals which continue to march along the library shelves.

In evaluating the impressions that these leave with the reader it is timely to inquire what are the qualities of a distinguished scientific journal. Foremost of these is the unwritten guarantee that within the covers will be found a high quality of professional accomplishment, and this in turn implies the feeling that to have a manuscript published therein is a reward of merit rather than an automatic right of membership. Lesser things, the format and color of the cover, the type-style and quality of the paper, and the taste in advertising, all play a part. In achieving all these the guiding hand of an able editor is indispensable, for editorial aberrations may badly mar the impression of otherwise impeccable journalism.

Some journals have these qualities and are the aristocrats of the scientific field. One which comes to mind is the "Annals of Applied Biology." Here is a publication to be read with pleasure, where rarely does a garish note intrude and where each issue guarantees original ideas and pioneer research. Surely, it is to these lofty heights that we should aspire.

The readers of the JOURNAL OF ECONOMIC ENTOMOLOGY are fully aware of the importance of editorial responsibility. The JOURNAL during its 47 years has had as distinguished editors, E. P. Felt, T. H. Frison, and L. M. Peairs, and has continued to grow in stature. However, during the hiatus engendered by amalgamation and reorganization when a strong editorial hand was lacking, our publication suffered many mishaps. The issues were months delayed, authors were plagued by omitted illustrations, corrections to galley proof were neglected, manuscripts were occasionally lost or separated, and names were confused. These incidents were a source of concern to our members and must have occasioned many a lifted eyebrow among our colleagues both at home and abroad. However, let us dismiss them as growing pains. For as we become of age with the celebration of the centennial of professional entomology in the United States, and the second year of consolidation of our professional societies, all is well. Under the able guidance of our present editor the issues of the JOURNAL appear more nearly on time, mistakes are nearly non-existent, manuscripts are edited with the best of taste, the quality of illustrations is improved, and a degree of selectivity is exercised in the subject matter accepted for publication. All these reforms are the stepping stones toward the production of a distinguished scientific journal, and their accomplishment is for the most part due to our conscientious and capable editor Fred W. Poos. To him, the editorial board wishes to say a hearty "well done," and to express the hope that he may long continue to serve.

R. L. METCALF,
University of California, Riverside

Common Names of Insecticides for Use in the Journal of Economic Entomology

H. L. HALLER, *Crops Research, Agr. Res. Serv., U.S.D.A.*

The Committee on Insecticide Terminology of the Entomological Society of America has revised and brought up to date the list of names of insecticides for use in the JOURNAL OF ECONOMIC ENTOMOLOGY. This list is confined to the principal organic compounds that have been developed as insecticides in recent years, the chemical names of which are too long for convenient use. For identification of these materials, the list includes their chemical definitions and other designations that have been given to them in the literature and elsewhere. The approved common names of a few fungicides with which entomologists frequently have to deal will be found at the end of this list.

Insecticides with common names that have been approved by the Interdepartmental Committee on Pest Control shall be called by those names. Some other materials are best known by their proprietary names or company numbers and their use seems to be justified if they are not competitive products; such names are capitalized. Other materials have designations that have become so firmly established through continued use that a change does not seem in order. A few comparatively short chemical names are used without the numbers or letters that indicate the position of the atoms or radicals in the molecule.

The names in the left-hand column may be used with no further explanation as to the chemical composition of the materials, but in reporting experimental work it should be made clear what formulations were used—whether wettable powders, emulsifiable concentrates, or dusts—and their concentrations.

This list supersedes the one approved at the 1951 meeting of the Association of Economic Entomologists and published in the February 1952 issue of the JOURNAL, Vol. 45(1): 165–6.

NAME TO BE USED IN JOURNAL	DEFINITION	OTHER DESIGNATIONS THAT HAVE BEEN USED
aldrin	not less than 95 per cent of 1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4,5,8-dimethanonaphthalene	compound 118
allethrin	*dl*-2-allyl-4-hydroxy-3-methyl-2-cyclopenten-1-one esterified with a mixture of cis and trans *dl*-chrysanthemum monocarboxylic acids	allyl homolog of cinerin 1 synthetic pyrethrins
Am. Cyanamid 12008	O,O-diethyl S-isopropylmercapto-methyl dithiophosphate	
Am. Cyanamid 12009	O,O-diethyl S-*n*-propylmercapto-methyl dithiophosphate	
Aramite	product containing 2-(*p*-tert-butylphenoxy) isopropyl-1-methylethyl 2-chloroethyl-sulfite	compound 88R alkyl aryl sulfite
azobenzene		azobenzide diphenyl diimide
Bayer 21/199	3-chloro-4-methylumbelliferone-O,O-diethyl thiophosphate	
Bayer 21/200	3-chloro-4-methylumbelliferone-O,O-dimethyl thiophosphate	
Bayer L 13/59	O,O-dimethyl 2,2,2-trichloro-1-hydroxy-ethylphosphonate	
BHC	1,2,3,4,5,6-hexachlorocyclohexane, consisting of several isomers and containing 12 to 14 per cent of the gamma isomer	benzene hexachloride 666 gammexane
Bulan	1,1-bis (*p*-chlorophenyl)-2-nitrobutane	CS-674A
butoxy polypropylene glycol		Crag Fly Repellent
butoxy thiocyanodiethyl ether	2-butoxy-2′-thiocyanodiethyl ether	Lethane 384
Chlorobenzilate	ethyl 4,4′-dichlorobenzilate	Geigy 338 G-23992
chlordane	1,2,4,5,6,7,8,8-octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene	chlordan Velsicol 1068 Octa-Klor Octachlor
chlorthion	O-(3-chloro-4-nitrophenyl)-O,O-dimethyl thiophosphate	Bayer 22/190
cyclethrin	*dl*-2-(2-cyclopentynyl)-4-hydroxy-3-methyl-2-cyclopenten-1-one esterified with a mixture of cis and trans *dl*-chrysanthemum monocarboxylic acids	
D-D mixture	mixture of 1,2-dichloropropane and 1,3-dichloropropene	D-D Dowfume N
DDT	commercially available dichloro-diphenyl-trichloroethane, the principal constituent of which is 1,1,1-trichloro-2,2-bis(*p*-chlorophenyl)ethane	chlorophenothane (U.S. Pharmacopoeia 14: 136. 1950)
p,p-DDT	1,1,1-trichloro-2,2-bis(*p*-chlorophenyl)ethane	
demeton	mixture of O,O-diethyl-S-ethylmercaptoethyl thiophosphate and O,O-diethyl-O-ethylmercaptoethyl thiophosphate	a trialkyl thiophosphate
Diazinon	O,O-diethyl O-(2-isopropyl-6-methyl-4-pyrimidinyl) thiophosphate	G-24480
dichloroethyl ether	beta,beta′-dichloroethyl ether	1-chloro-2(beta-chloroethoxy)ethane
dichlorophenyl benzenesulfonate	2,4-dichlorophenyl benzenesulfonate	Genite Genitol 923
dieldrin	not less than 85 per cent of 1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a-5,6,7,8,8a-octahydro-1,4,5,8-dimethanonaphthalene	compound 497
diisopropyl parathion	O,O-diisopropyl O-*p*-nitrophenyl thiophosphate	compound 3456
Dilan	mixture of 1 part of Prolan and 2 parts of Bulan	CS-708
dimefox	bis(dimethylamino)fluorophosphine oxide	Hanane
dimethyl carbate	dimethyl cis-bicyclo [2.2.1]-5-heptene-2,3-dicarboxylate	
dinitrobutyl-phenol	4,6-dinitro-*o*-sec-butylphenol	Dinoseb DNOSBP
dinitrocyclohexylphenol	4,6-dinitro-*o*-cyclohexylphenol	DNOCHP Dinex
dinitrocresol	4,6-dinitro-*o*-cresol	DNOC DNC Sinox
dithiocyanodiethyl ether	beta,beta′-dithiocyanodiethyl ether	Lethane A-70
DMC	4,4′-dichloro-alpha-methylbenzhydrol	di(*p*-chlorophenyl) methylcarbinol 1,1-bis(*p*-chlorophenyl)ethanol Dimite
endrin	1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4,5,8-endo-endo-dimethanonaphthalene	compound 269
EPN	O-ethyl O-*p*-nitrophenylbenzenethiophosphonate	EPN-300
ethyl hexanediol	2-ethyl-1,3-hexanediol	Rutgers 612
furethrin	*dl*-2-(2-furfuryl)-4-hydroxy-3-methyl-2-cyclopenten-1-one esterified with a mixture of cis and trans *dl*-chrysanthemum monocarboxylic acids	
heptachlor	1 (or 3a),4,5,6,7,8,8-heptachloro-3a,4,7,7a-tetrahydro-4,7-methanoindane	Velsicol 104 E-3314
HETP	mixture of ethyl polyphosphates containing 12 to 20 per cent of tetraethyl pyrophosphate	hexaethyl tetraphosphate
Holcomb compound 326	O,O-diisopropyl dithiophosphoric acid ester of N,N-diethyldithiocarbamic anhydrosulfide	

NAME TO BE USED IN JOURNAL	DEFINITION	OTHER DESIGNATIONS THAT HAVE BEEN USED
Indalone	butyl 3,4-dihydro-2,2-dimethyl-4-oxo-2H-pyran-6-carboxylate	*n*-butyl mesityl oxide oxalate butopyronoxyl
isobornyl thiocyanoacetate		terpinyl thiocyanoacetate
isochlorthion	O-(2,-chloro-4-nitrophenyl)-O,O-dimethyl thiophosphate	Thanite compound 4124
isodrin	1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4,5,8-endo-endo-dimethanonaphthalene	compound 711
Isolan	dimethyl 5-(1-isopropyl-3-methylpyrazolyl) carbamate	G-23611
lauseto neu	chloromethyl *p*-chlorophenylsulfone	
lindane	gamma isomer of BHC of not less than 99 per cent purity	gamma BHC
malathion	O,O-dimethyl-S-(1,2-dicarboxyethyl)dithiophosphate	malathon compound 4049
Metacide	product containing methyl parathion and parathion	
methoxychlor	1,1,1-trichloro-2,2-bis(*p*-methoxyphenyl)-ethane	Marlate DMDT
methyl parathion	O,O-dimethyl O-*p*-nitrophenyl thiophosphate	methyl homolog of parathion
MGK 264	N-(2-ethylhexyl)bicyclo [2.2.1]-5-heptene-2,3-dicarboximide	Octacide 264 Van Dyk 264
mipafox	bis(isopropylamino)fluorophosphine oxide	
Neotran	product containing bis(*p*-chlorophenoxy)-methane	di(4-chlorophenoxy) methane K-1875
NPD	tetrapropyl dithiopyrophosphate	
Ovotran	product containing *p*-chlorophenyl *p*-chlorobenzenesulfonate	K-6451
para-oxon	diethyl *p*-nitrophenyl phosphate	oxygen analog of parathion E-600
parathion	O,O-diethyl O-*p*-nitrophenyl thiophosphate	E-605 compound 3422
Perthane	1,1-dichloro-2,2-bis(*p*-ethylphenyl)ethane	Q-137
piperonyl butoxide	product containing as its principal constituent alpha-[2-(2-butoxyethoxy)-ethoxy]-4,5-methylenedioxy-2-propyltoluene	(butyl carbitol) (6-propylpiperonyl) ether compound 312
piperonyl cyclonene	mixture of 3-alkyl-6-carbethoxy-5(3,4-methylenedioxyphenyl)-2-cyclohexene-1-one and 3-alkyl-5(3,4-methylenedioxyphenyl)-2-cyclohexen-1-one	piperonyl cyclohexenone
Pirazinon	O,O-diethyl 3-(2-propyl-6-methyl-4-pyrimidinyl)thiophosphate	G-24622
Potasan	4-methylumbelliferone O,O-diethyl thiophosphate	E-838 O,O-diethyl thiophosphoric acid ester of 7-hydroxy-4-methylcoumarin
Prolan	1,1-bis(*p*-chlorophenyl)-2-nitropropane	CS-645A
propyl isome	di-*n*-propyl-2-methyl-6,7-methylenedioxy-1,2,3,4-tetrahydronaphthalene-3,4-dicarboxylate	*n*-propyl isome
Pyrazoxon	O,O-diethyl O-5-(3-methylpyrazolyl)phosphate	G-24483
Pyrolan	dimethyl 5-(3-methyl-1-phenylpyrazolyl)carbamate	G-22008
schradan	octamethyl pyrophosphoramide	bis(bis-dimethylamino) phosphonous anhydride Pestox III OMPA
sesamin	2,6-bis(3,4-methylenedioxyphenyl)-3,7-dioxabicyclo [3.3.0] octane	
sesamolin	2-(3,4-methylenedioxyphenyl)-6-(3,4-methylenedioxyphenoxy)-3,7-dioxabicyclo-[3.3.0] octane	
Strobane	a terpene polychlorinate with a chlorine content of approximately 66 per cent	compound 3961
sulfotepp	O,O,O,O-tetraethyl dithiopyrophosphate	dithione Sulfatep
sulfoxide	*n*-octyl sulfoxide of isosafrole	Sulfox-Cide
Sulphenone	product containing *p*-chlorophenyl phenyl sulfone and related sulfones	R-242
Systox	product containing demeton	
TDE	commercially available dichloro-diphenyl-dichloroethane, the principal constituent of which is 1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethane	DDD Rhothane tetrachlorodiphenyl-ethane
TEPP	tetraethyl pyrophosphate	TEP
thiocyanoethyl laurate	beta-thiocyanoethyl laurate	Lethane 60
toxaphene	chlorinated camphene having a chlorine content of 67–69 per cent	compound 3956

NAME TO BE USED IN JOURNAL	DEFINITION	OTHER DESIGNATIONS THAT HAVE BEEN USED
	Fungicides	
captan	N-trichloromethyl thiotetrahydrophthalimide	Orthocide
chloranil	tetrachloro-*p*-benzoquinone	Spergon
dichlone	2,3-dichloro-1,4-naphthoquinone	Phygon
ferbam	ferric dimethyl dithiocarbamate	Fermate Karbam, black
glyodin	2-heptadecyl glyoxalidine acetate	Crag Fruit Fungicide 341
maneb	manganese ethylene bisdithiocarbamate	Manzate Manganese EBD
nabam	disodium ethylene bisdithiocarbamate	Dithane D-14 Parzate, liquid
thiram	tetramethylthiuram disulfide	Arasan
zineb	zinc ethylene bisdithiocarbamate	Dithane Z-78 Parzate, dry
ziram	zinc dimethyl dithiocarbamate	Zerlate Karbam, white

Publication Policies and Manuscript Rules and Suggestions for the Journal of Economic Entomology

The Governing Board of the Entomological Society of America has defined the fields of interest for the *Annals of the Entomological Society of America* and the JOURNAL OF ECONOMIC ENTOMOLOGY as follows:

"*The Annals.* The areas of interest for this publication should include the fields of classical entomology sometimes termed 'academic,' such as taxonomy, biology, morphology, and normal physiology. Contributions accepted need not have as their objective immediate economic application or utility.

"*The Journal.* The areas of interest for this publication should include such fields as chemical or biological control, surveys, regulation, toxicology, and abnormal physiology. In general, contributions accepted should have as their objective, sometimes indirectly perhaps practical application or utility.

"In the case of papers which might go to either publication the editors should be governed by the historical character of each publication, and the objectives, expressed or in context, of each paper."

The Governing Board of the Entomological Society of America unanimously approved the following resolution:

"BE IT RESOLVED that the Governing Board approves the policy that no manuscript which has been published elsewhere, either wholly or in essential part, will be accepted for publication in the ANNALS OF THE ENTOMOLOGICAL SOCIETY OF AMERICA or the JOURNAL OF ECONOMIC ENTOMOLOGY. Authors submitting papers to these journals are earnestly requested to cooperate in the administration of this policy."

It should, therefore, be understood that articles submitted for publication in the *Journal* have not appeared previously elsewhere, and that they will not be offered for simultaneous publication in other journals without the consent of the Editor of the JOURNAL OF ECONOMIC ENTOMOLOGY.

Papers acceptable for publication shall in general consist of progress or final reports on original biological or biochemical research and its application in the field of applied entomology and closely related fields, including quarantine activities. Other papers dealing with economic entomology, such as papers dealing with important insect problems, or reports on large-scale control activities may be accepted at the discretion of the Editor with the approval of the Editorial Board. In the consideration of papers, an important factor shall be the value of such papers in the field of economic entomology. The primary criteria for approval of an article for publication will be the scientific merit of its content and the clarity and conciseness of its manner of presentation. If the Editor's decision is challenged, he shall refer the matter to the Editorial Board.

Preferably, each paper should be accompanied by the written approval of one or more persons familiar with the subject. Every paper is read and criticized by one or more reviewers. The author is subsequently given an opportunity to revise the paper in accordance with the reviewers' comments. If revisions are made all pages of the original manuscript, as well as any retyped ones, must be returned to the Editor in order to receive prompt consideration. This procedure is not intended to imply any reflection on the merits of individual papers but is solely for the purpose of improving the quality of articles appearing in the JOURNAL OF ECONOMIC ENTOMOLOGY and to reduce publication costs. Papers are unacceptable if conclusions are obviously unsound or based on faulty experimental methods or inadequate data. Acceptable papers must be in accord with the rules and suggestions printed in the *Journal*. When the Editor or the Editorial Board finds that a paper is unacceptable it will be returned to the author promptly with an explanation for not accepting it.

Papers, including Scientific Notes, by non-member authors who are regularly employed as entomologists may

be accepted for publication under the condition that publication costs are paid. This requirement shall not apply to invitation papers included in the general sessions of the Society. If they are of general interest and otherwise acceptable, they may be published free. Other papers by non-members, if sufficiently meritorious, may be published free upon approval by the Editor and the Editorial Board.

All papers by members of the Society accepted for free publication shall be published in the approximate order of their receipt in final form for publication by the Editor. The date of receipt of articles or scientific notes in acceptable form shall be published with each paper. Scientific notes are accepted for publication in the approximate order of their receipt independent of that of other papers. Scientific notes shall be indexed and their titles shall be included in the table of contents.

A paper accepted for publication which would occupy less than two pages of the JOURNAL OF ECONOMIC ENTOMOLOGY in 9 on 10 point type, including illustrations and tables, shall be published as a Scientific Note, except as may be agreed upon by the Editor and one member of the Editorial Board.

Suggestions. The following are presented in order to minimize revisions and editorial corrections. Uniformity of style and format necessitates attention to detail by authors even though many points may seem arbitrary. The cooperation of authors in the preparation of manuscripts will permit the publication of greater numbers of papers with the funds available.

Papers containing data on unknown chemicals, designated only by code, symbol, or generic name must have the composition fully disclosed or they will not be accepted for publication in the JOURNAL OF ECONOMIC ENTOMOLOGY. Authors should describe clearly and specifically the materials with which they are working, giving their nature and their composition. In reporting experiments with formulations such as wettable powders and emulsifiable concentrates authors should give the concentration of the active ingredient and in indicating dosages make it clear whether they are in terms of the formulation or of the active ingredient. In reports of certain experiments it may also be desirable to include other ingredients in the formulation. Use of the common names of insecticides and the interim designations of insecticides which have been approved by the Committee on Insecticide Terminology of the Entomological Society of America is mandatory in the JOURNAL OF ECONOMIC ENTOMOLOGY. Use of the common names of insects which have been approved by the Committee on Common Names of Insects of the Entomological Society of America is also mandatory in the JOURNAL OF ECONOMIC ENTOMOLOGY. Authors are urged to consult the latest published lists before preparing their manuscripts for the *Journal*.

The title of a paper should be short and concise. Authorship should be restricted to those who *actually planned and conducted* the work reported. The manuscript should be clearly typewritten on opaque paper, double spaced (including footnotes, citations, and legends) on one side of the paper only. The ribbon copy is required. The sheets should not be stapled or pinned. It should be mailed flat; not folded or rolled. Pages should be numbered consecutively. Author's complete address to which proof is to be sent should appear at upper right-hand corner of first page. Number footnotes consecutively with Arabic numerals, except in tables, where lower case letters should be used. Footnotes are referred to by means of superscript numerals or letters. Text footnotes should be typed double-spaced, in consecutive order on a separate sheet of paper and put at the end of the manuscript. Sub-headings intended to be set by themselves in the middle of a page should be avoided. Appropriate side headings should be used; not more than two per typewritten page meet most needs. They should be informative, not mere labels or tags. Pages that are heavily corrected should be retyped. Do not insert corrections and additions along the margin; the printer works with the typescript mounted in a frame that exposes only a few lines at a time.

Tables are expensive. They should always be reduced by the authors to the simplest form and withdrawn if text or illustrations give the same information. Tables should be typed double-spaced, on separate sheets of paper, one table to a page, numbered consecutively, and placed in a group at the end of the manuscript. Give each table a clear, concise heading stating its contents. When headings for a number of tables are similar, an attempt should be made to combine the tabular data thereby avoiding repetition of the same heading. Use a double horizontal line immediately below the title of the table and a single horizontal line below the column headings and at the bottom of the table. Do not use horizontal lines in the interior of the table. Use no vertical lines. Tables should be arranged so that, regardless of their length, the number of columns is reduced to the minimum. Papers submitted with more tables than seem necessary, or with tables poorly arranged, will be returned to the author for modification.

Illustrations should be clear and unquestionably suitable for reproduction. They are accepted only when they contribute materially to the information presented in the paper. Data should be presented in tables rather than graphs when the nature of the data permits a choice. Graphs and other line drawings should be so constructed that the greater dimension is vertical rather than horizontal. Lines on the drawings, as well as letters and figures, should be heavy enough to stand reduction without losing their clearness. Waste space should be kept to a minimum. They should be drawn on pure white paper or light blue cross-hatched paper, for satisfactory reproduction. Tracing paper or cloth is satisfactory where there may be an advantage in its use. Good photographs, when available, should accompany obituaries.

Illustrations are run as text figures designated by Arabic numerals. Units of a composite illustration are designated by letters. Arrange full-page figures to conform to *Journal* proportions ($6\frac{1}{8} \times 9$ inches, including legend), making due allowance for reductions. Magnification stated in the figures or in the explanation of the figures should refer to the magnification after reduction. A scale may be drawn on the figure which will automatically indicate the size of the original regardless of reduction. Line drawings for reproductions are often made larger than necessary. If carefully drawn they need be no

more than 50 per cent larger than the size desired when in print. Original drawings should be submitted for making engravings. In addition to the original illustrations, a photographic copy of each (no larger than $8\frac{1}{2}\times11$ inches) should accompany the manuscript to facilitate transmittal to reviewers. Specific reference to each illustration must be made in the text. Use of illustrations not original with the authors must bear permission for use and credit to the originator.

Legends of figures should never be made a part of the copy. They should be typed double-spaced on a separate paper and identified by the figure number. Each piece of copy for engraving should bear on its back the name of the author and the title of the article it is to accompany, as well as the figure number corresponding to that used with the legend in the text. Cracks and marks made by paper clips or pressure of writing ruin photographs for reproduction.

Used engravings may be secured by authors who desire them if application is made to the Editor within 60 days of their publication.

References Cited. References to scientific literature, unpublished reports, and personal communications should be accumulated in a list, arranged alphabetically by author's last name and typed double-spaced on a separate sheet of paper at the end of the text. Citations should give author's name, year, title, name of publication, volume, number of issue or month, and pages, in the order named. Examine Volume 48 issues of the *Journal* for the detailed form.

No paper will be published until the author or his representative has had an opportunity to read and correct a galley proof unless otherwise instructed by the author. Alterations on the galley proof should be limited to typographic and factual errors. Additional costs to the Society for correction of errors in galley proof for which authors are responsible may be charged to authors. Corrected proof, *together with the original manuscript*, should be returned to the Editor as promptly as possible. The abstract requested for *Biological Abstracts* may be returned to the Editor later if its preparation delays return of proof beyond 48 hours.

Reprints. No gratis copies of reprints are supplied. An order form is sent to authors with galley proof. Orders placed before the issue is printed will be furnished in accordance with the following price schedule.

Reprint Price Schedule

Transportation Costs to be Added

	Pages							
	1–4	5–8	9–12	13–16	17–20	21–24	25–28	29–32
50 copies*	$ 8.20	$11.10	$12.60	$15.35	$18.30	$21.85	$24.05	$25.05
75 copies	10.20	14.25	16.25	20.15	24.15	28.65	31.65	33.05
100 copies	10.70	15.30	18.30	22.05	26.45	31.20	34.55	36.20
Addl's 100's	2.10	4.20	6.60	7.50	9.30	10.20	11.70	12.60

* No order for less than 50 copies accepted.

Changing page numbers, 60¢ per page additional.

Remaking pages, $1.25 per page additional.

Reimposing, $1.00 per page. Charge applies when the reprint cannot be printed while the *Journal* itself is being printed, either because the order was received too late or because of requests for changes in content.

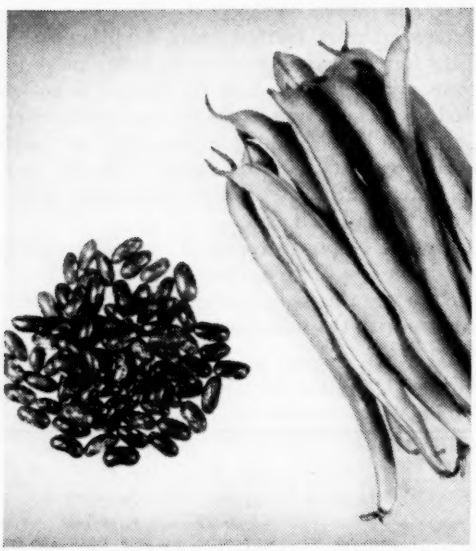
Covers	
50 copies	$7.60
75 copies	8.30
100 copies	9.00
Add'l 100's	2.80

The Annual Review of Entomology is Coming.

Watch for its Announcement.

ARAMITE®

KILLS MITES



The safest, most effective mite killer

Aramite, today's safest strongest mite-killer, promises growers bigger, more profitable yields of better fruits, vegetables, row crops, cotton and ornamentals. This is possible because Aramite can effectively control a wide variety of mites at low cost per acre without harming humans, animals or crops. Further advantages of Aramite are ease of use, long residual effect, high compatibility and harmlessness to natural predators.

Naugatuck Chemical

Division of United States Rubber Company

Naugatuck, Connecticut

producers of seed protectants, fungicides, miticides, insecticides, growth retardants, herbicides: Spergon, Phygon, Aramite, Synklor, MH, Alanap, Duraset.

US RUBBER

CLASSIFIED

FOR SALE: Journal of Economic Entomology. Complete sets of Volumes Nos. 7, 8, 9, 10, 17, 20, 21, 43 and 46. Incomplete sets as follows: Vol. 13, No. 1 only; Vol. 20, Nos. 1, 2 and 6; Vol. 22, Nos. 1, 2, 4, 5, 6; Vol. 23, Nos. 1, 2, 3, 4, 6; Vol. 24, Nos. 2, 3, 4, 6; Vol. 44, No. 1 only; Vol. 45, Nos. 1, 2, 5, 6. Complete volumes $3.00 each, not to be broken. Incomplete sets 50¢ each number, plus postage on small orders. Also Index Special Publication No. 7, 1940-1944. T. F. McGehee, Box 472, Gulfport, Mississippi.

POSITION WANTED by Entomologist, M.S., 34, married, children. Experience includes commercial pest control, insect detection and supervision of control operations, teaching vocational agriculture. Desires Entomology research or experiment work, laboratory and/or field work. Reply to Box V, Entomological Society of America, 1530 P Street, N.W., Washington 5, D.C.

BOOKS FOR SALE: Blatchley—Heteroptera or True Bugs of Eastern North America, 1926, 1,116 pp., 12 plates, 215 figures, 1,253 species treated. Cloth Bound, $10.00.

Blatchley—Orthoptera of Northeastern America. 1920, 784 pp., 7 plates, 246 figures. Paper Binding, $5.00.

Blatchley and Leng—Rhynchophora or Weevils of Northeastern America. 1916, 682 pp., 155 figures, 1,084 species treated. Paper Binding, $4.00.

Blatchley—Coleoptera of Indiana. A very few newly bound copies of this rare book available, $50.00.

Blatchley Nature Study Club, Noblesville, Indiana

FOR SALE: Journal of Economic Entomology, Vols. 1 through 33, complete, covering the years 1908 through 1940, each volume bound in maroon buckram; in very good condition; $150.00 f.o.b. Los Angeles, California. Leland R. Brown, Dept. of Entomology, University of California, Los Angeles 24, California.